ABOUT THIS EARTH

An Introduction to the Science of Geography

by

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Founder's Medal, Royal Geographical Society; Livingstone Medal, Royal Scottish Geograpical Society; Veitchian Medal and Victorian Medal, Royal Horticultural Society; Robert White Medal, Massachusetts Horticultural Society

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To the Memory of
EVELYN HADFIED
P.N.E.U.

PREFACE

This is not a Text-book of Geography. It is a book about what geography is about, and is designed to make intelligent people who are not primarily geographers realize how interesting the study of the Earth can be. In spite of the twentieth-century revolution in geographical teaching in Great Britain — a revolution brought about largely by the efforts of the late Prof. Herbertson, the late Dr. Scott Keltie, by Sir Halford Mackinder and by Dr. H. R. Mill and their disciples, there is still much to be done in improving such teaching. Too many educated people particularly amongst politicians and captains of industry still think of geography in terms of place names. They say: 'Since the war I have learnt a lot of geography' — meaning, that they can now find places on the map which formerly they could not find and had probably never even heard of. A very useful accomplishment; but it bears about the same relation to geography that the alphabet bears to English Literature. Modern geography covers wide fields of learning and is always extending its boundaries — some might say encroaching on others' preserves. It is not possible within the limits of a short book to touch on every division of so vast a subject, and I have confined myself to what may be called Brains Trust geography and conversational topics. I have purposely avoided any reference to maps and survey — a highly technical subject — because although maps are the very foundation of modern geographical study they are also the result of a deep knowledge of geography.

In writing any semi-popular general scientific book one must inevitably select from and incorporate the ideas and observations of many workers in the same field. Much of the work of geographers from Strabo and Herodotus to Mackinder and Dudley Stamp has passed into the common stock of knowledge on which all may freely draw; nevertheless I have tried to acknowledge the source of recent ideas when known to

me. A few minor ideas and observations set forth, as well as the general plan of the book, are original; they constitute the writer's modest contribution to our common scientific heritage. At least they are the result of many years of active exploration in the limited field of South-East Asia. They may be accepted or rejected by geographers.

F. K.W.

Khowang Tea Estate
Assam.
1945

I

THE SCOPE OF GEOGRAPHY

GEOGRAPHY is not directly concerned with what man *does* on the Earth — that is the subject of history — but with what he *is*. But what he does is to some extent influenced by his environment, and *why* he does may also come within range of the geographer. Hence the results of what he does belong to geography almost as much as to history. It is therefore important to understand the conditions which chiefly influence what man does. Before we discuss his special environment, however, we need to have a clear conception of the Earth as a whole, regarded as one of the planets of our solar system and, so far as we know, the only inhabited planet. The atmosphere of Mars, including its oxygen content, is only half the weight of our own, equivalent to the Earth's atmosphere at an altitude of about 18,000 feet. It contains very little water vapour and would be both cold and dry, giving us unpleasant sore throats. Venus is a dead world — its atmosphere consists of carbon dioxide, which neither animals nor plants can breathe. The modern geographer must view the Earth, not as a surface made up of land and sea, but rather as a planet whose living space is thinly three-dimensional.

On a distant view, the Earth is seen to be composed of three concentric envelopes or shells, atmosphere, hydrosphere, lithosphere, one inside the other, each completely, or almost completely, enclosing the next smallest; the innermost enclosing the vastly thicker solid core of the Earth. The combined thickness of these three shells, compared with the core, is much thinner than the shell of, say, an ostrich's egg, compared with the yolk inside it. But of course to man, who has no direct acquaintance with the core, the shell is of considerable thickness; nor is it possible for him anywhere to break out of it,

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although when he flies in the stratosphere he comes very close to its limits

When the Earth was born, what is now a triple shell enclosing the core had not yet formed There was no crust, no core either The new born planet, so it is thought consisted of hot gases in a state of violent agitation Gradually the matter of which it was composed concentrated, the heavier stuff towards the centre, the lighter on the outside Thus the first 'shell' to form, visible from afar perhaps as glowing cloud, was gaseous Eventually it separated into two distinct shells, as some of the gases combined to form water, which not merely filled up hollows on the cooling crust, but probably covered the entire surface Meanwhile a solid crust was forming underneath the two fluid shells until finally all three — solid, liquid, gaseous — were differentiated

We are dealing now with astronomical time Events such as those described, of whose development we know nothing only recognizing the final result, must have required hundreds of millions of years for their completion But at last comparative stability was reached, with two fluid shells, the atmosphere or air, and the hydrosphere or sea enclosing a solid Earth Supporting these two shells was a third shell, comprising the cool hardened lava like surface of the otherwise hot and plastic core This cool hard surface is the crust

Rock is a poor conductor of heat, so that it would not need a very thick skin or crust to insulate the still white hot interior and at the same time allow the swirling gases to condense on the outer surface On the other hand the condensation of gases into water would place a heavy strain on the thin crust, which might break up again and again under the weight, allowing the hot rock beneath to vaporize the water once more, thereby starting the cycle all over again Obviously it would take a long time to stabilize the position and our suggested hundreds of millions of years can be no exaggeration

We must not however, imagine the crust as completely divorced from the core What we see to-day is only the exterior,

in its most altered state. In fact the real outermost crust is largely covered by and hidden beneath sedimentary rocks which are of much later origin. In their present shape they never did form part of the original planet, though many of them have been altered by pressure and heat in such a way as to suggest that they did. Beneath the crust, the core differs both in composition and in its physical state from the hard exterior; though the core itself may consist of concentric layers. But the one passes gradually into the other, with no obvious break. It is convenient to compare the rigid crust surrounding a plastic core with the solid shell of an egg; that is to say, to regard it as a separate wrapping enclosing a different substance. But if we could bore through the crust for twenty miles or so, we should not find a break comparable with that of an egg inside its shell.

Yet the core of the Earth *is* of a different composition from that of the crust, its materials stratified, as basalt, olivine, and finally iron, in accordance with the physical law that the heaviest substances in a rotating fluid sphere concentrate towards the centre of the system. Thus, taking all the wrappings and materials of the Earth, we find them arranged from without inwards in this order: air, water, crystalline rocks, and then, it is believed, basalt, olivine, and finally iron, in thick concentric spheres.

However, the geographer need not and in fact should not encroach too far into the realms of astronomy and geophysics. He accepts the findings of other scientists in order to obtain a rational view of the Earth; and with that as a starting point he is wise to be content.

When the Earth's crust was at last stabilized and condensation of vapour was complete, it is probable that the hydrosphere or sea formed a complete shell, so that nowhere was the crust in contact with the atmosphere; in other words there was no land. That the sea could very easily swallow up the land to-day, leaving no trace, is obvious if we consider their relative bulk. For the average depth of the sea is about two miles, and

the average height of all the land above sea-level not more than 2300 feet, or less than half a mile. Moreover the area of the sea is almost three times the area of the land; as it is, the sea has encroached over the continental shelf to the extent of about ten million square miles. Thus it would seem that the fact of there being any land at all is surprising. Somehow the crust has in places pushed aside the sea, and emerged above it to become visible crust or land.

But though displaced, the land crust has not entirely rid itself of the hydrosphere which once covered it; in the form of rivers and lakes, rain, snow, dew, the hydrosphere reappears as land-based water. It is as though the land had emerged dripping, and had not yet shaken off all the water which clung to it. It is however not strictly true that the crust is everywhere the same, whether visible as land or invisible beneath the ocean. The crust is continuous over the interior core, but it is not uniform. The continental land-masses appear to be blocks of lighter material, floating deeply in a slightly denser material, so that they may be roughly compared with ice-bergs floating in the sea, seven-eighths submerged, and perhaps, like ice-bergs, sometimes aground. At least that is what some geographers would like the continents to be, although it seems very improbable that they really are 'floating' just like that. The crust does seem more continuous than the ice-berg simile suggests, even though ice-bergs are merely solid water. Moreover, if this view is correct we are faced with the difficulty that there must always have been continents and hence that the lithosphere never was homogeneous, though we started with the assumption that it was.

How far has the crust been pushed up? Mount Everest, apparently the highest known mountain in the world, rises 29,143 feet, or nearly six miles above sea level. But the sea itself has an average depth of about two miles, with a maximum of about seven miles, making nearly thirteen miles in all. In fact, Mauna Loa, an active volcano in the Hawaii group, 13,675 feet above sea-level, rises directly from an ocean depth of 16,000

feet, and is thus over 500 feet higher than Mount Everest. Taking the Earth's surface as a whole, the maximum irregularities of the crust, from the greatest ocean depths to the highest mountain tops, amount to between twelve and thirteen miles. This may seem a lot, but it is only a very small fraction of 4000 miles, which is the radius of the Earth.

The mechanism of mountain building is highly complex, and does not come within the scope of this book though it will be briefly referred to later. The plastic or flexible crust of the Earth, as it cooled, has repeatedly buckled, and being composed of materials of different hardness and strength has thereby been thrown into irregular folds, ridges or mountain chains. In extreme cases a difference of height amounting to about twelve miles has been achieved. Perhaps under these conditions, it is impossible that it should *not* have buckled. But it seems rather remarkable that the crust should have been forced up against the enormous weight of the sea, to a height of several miles above its surface. For even allowing that it must change its shape, it might, being unable to adjust itself neatly to a shrinking core, just as easily have collapsed and sunk. When we consider that in every four square miles of the Earth's surface, nearly three square miles is sea, with a depth perhaps of two miles, we may well be surprised at the forces beneath the crust.

Nor is that the whole story. For not only has the surface crust buckled in such a way as to lift up mountains, but plains also have been uplifted ready-made out of the sea, and that in times which, by geological standards, were but as yesterday. And it is difficult to invoke buckling to account for that, since many of the plains are in fact *not* buckled. True, coastal plains are usually raised only a few hundred feet, and were already part of the land surface over which the sea had intruded. However, it is not unreasonable to suppose that the same internal force which could raise up mountains might, acting more gently, raise up plains.

Whatever forces have been at work, the fact remains that the crust has somehow been upraised to form dry land, and that

no sooner does it appear out of place, in contact with the atmosphere, than it is assailed hammer and tongs by air and sea, which, largely owing to its very presence, have been stung to action It would almost seem as though land tends to destroy itself, by galvanizing the fluid shells to a fury they would never know but for the presence of land

Yet protection was to be had, and by means of an armour of vegetation the land protected itself against the worst ravages of climate, not completely, but fairly well The cynical may observe that for the last 500 years man has been redoubling his efforts to destroy the vegetable armour of the land, which for untold aeons has been its shield, and that in one year he can now undo work which may take many centuries to repair

It would seem then that a complete hydrosphere was to be expected, that water is the rule, land rather the exception Yet had there been no land, life would have appeared in the sea just the same, though there would have been no air breathing animals — no whales or porpoises even, and mermaid rather than man might have been the highest form of life

The geographer has then to deal with the Earth as he finds it, an Earth that is to say, consisting of three concentric hollow spheres, the innermost finally enclosing a vastly larger core, which is the bulk of the planet beneath the crust The three spheres consist of matter in three different states gaseous, liquid and solid, the two outer fluid and easily permeable, the inner hard and solid The core itself grows denser as we proceed towards the centre and is believed to consist of heavier and heavier layers, or shells, passing gradually into one another, yet essentially distinct The very heart of the Earth is thought to consist of iron This is overlaid by a thick shell of olivine, and this in turn by a shell of lighter rock, known as basalt The basalt shell passes gradually upwards into the crust, which consists largely of crystalline rocks, surfaced over three-quarters of the land area by sedimentary rocks But all this is invisible It was the behaviour of earthquake waves that gave the clue for this piece of detection

Resting on the crust is, as we know, the hydrosphere, which is liquid, except at the Earth's poles, where it is solid ice; and resting on the hydrosphere is the even more fluid atmosphere, the last of the Earth's envelopes, which becomes gradually thinner as we proceed outwards towards space, until at a height of less than twenty miles above the Earth's surface it could not be detected by any instruments we possess.

All these shells are complete — all three visible shells at any rate, with the exception of the hydrosphere, which is interrupted here and there by the crust breaking through it to come into direct contact with the atmosphere, as land. And this, as I have already pointed out, seems to be an unexpected development.

The stage is set. Life appears as a thin film lining the interior of the outermost shell, that is to say the atmosphere, but mainly confined to the land and sea surface, whence it penetrates both fluid spheres for a short distance only. Nevertheless it occupies not simply a surface but the thickness of a three-dimensional but thin-walled shell. And since geography deals with man's relationship with the Earth and all that it contains, he is especially concerned with Life, and with its highest form, Mankind. A dead world like the moon is no concern of his.

Much of the variety of environment we see on every hand is due to climate, a particularly inconstant factor of great importance in the evolution and distribution of life. Temperature and humidity are indeed two of the most potent forces in the geographical armoury. There are also the various land forms — mountains, plains, rivers, lakes, deserts, which help to make up man's surroundings and influence his life and actions. These are the more important controlling factors of which the geographer must take notice.

Such then is the geographer's world and the starting point of his investigations.

Before we turn to the more obvious materials of geographical study, it will be convenient to discuss a little more fully the interaction of the Earth's three hollow spheres.

II

AIR, LAND AND SEA

It has been suggested that the existence of any land at all is rather remarkable. At least we know that there is more than enough water to drown the entire land surface. But land there is, and it owes its existence in the first place to forces within the Earth, deep beneath the crust.

What we call land is that part of the lithosphere, or crust, the innermost of the three shells enclosing the Earth's core, which has broken through the fluid middle shell, to come into direct contact with the outermost shell, the still more fluid atmosphere. It is to that extent crust misplaced and the consequences of its misplacement have been momentous. Without land there would certainly be no air-breathing plants or animals, including birds and insects, since these too developed on land. For though birds have taken to the air as a means of progression, they cannot indefinitely remain aloft without coming down to land. Even those sea birds which rarely come to land originated from land-based birds. In fact, there would be little change of any kind.

The first obvious sub-division of the Earth's features is therefore into air, sea and land (or up-crust) corresponding with everyday experience; that is to say with the three outer shells including as much of the lithosphere as is open to our inspection. Each of the three has its own peculiar composition, structure and properties.

Without land much besides land life would be lacking, for the interaction of the two fluid shells alone has little visible effect. There would still be cloud and rain, but on a much reduced scale. Winds would cause waves, but they would be gentle winds, though constant, and the small waves would have nothing to beat against. Violent storms would be unknown.

At the Earth's poles there would still be ice, though much less than there is now, and the equatorial seas would still be warm. Ocean currents would be feeble. There would be day and night, and the colours of sunrise and sunset, though paler than we know them, because there would be no dust in the atmosphere and little vapour. In fact sunset might be somewhat harsh. Mountains, valleys, plains, deserts, jungle there might be, but they would be invisible under the sea.

The sea would be as full of life, both animal and plant, as it is to-day, except for the absence of mammals. But the crust beneath would be more uniform. Some of the varied scenery met at depths of several hundred feet round our coasts may have been etched on the land before it sank under the sea; for the continental shelf is drowned land, and what was sculptured on its surface when it was above the sea has persisted. Drowned valleys or fjords as on the coast of Norway are an example.

Thus the presence of crust in contact with the atmosphere has enormously altered the face of the Earth. It has stepped-up all physical interactions, started new ones. The normal sequence $\left\{\begin{array}{l}\text{Atmosphere}\\ \text{Hydrosphere}\\ \text{Lithosphere}\end{array}\right\}$ results in only gentle action. But when the normal sequence is interrupted, so that we get $\left\{\begin{array}{l}\text{Atmosphere}\\ \text{Lithosphere}\\ \text{Hydrosphere}\end{array}\right\}$ action becomes violent.

Land, air and sea apart are inert. Only the rotation of the Earth and tidal action gently stir the fluid shell. Bring all three into contact and the result is dynamic. The interaction is not only physical, but also chemical. It is because all three shells are in contact, not two only, that violent movement takes place in the fluids. The results of these agitations are permanently recorded on the intruding land surface. The land is the score-board. It shows the state of the game everywhere — if we can read it.

But though the land was, we believe, originally heaved up

from the floor of the ocean, it is to-day, after the lapse of thousands of millions of years, rather different in composition, and still more different in structure, from the original crust on which the first seas condensed

One reason for this is that the continental platforms are by now largely composed of, or overlaid by, stratified rocks which cover three-quarters of the land surface

Stratified rocks are laid down layer by layer in the sea or in lakes, only exceptionally on land Hence any land composed mainly of stratified rocks must at some time have been under the sea It was raised from the sea to form land On the contrary, land composed of crystalline or unstratified rocks has not been under the sea since it was first raised above the sea, otherwise it would have been overlaid by stratified rocks, deposited on it while it was submerged Of course, it might have been covered by stratified rocks which have since been denuded, but it is hardly likely that they would leave no trace

Large portions of the land blocks are to-day overlaid by sedimentary rocks, and it can be shown that much of the crust has been alternately submerged and upraised and submerged again several times The hills are not perhaps so everlasting as they seem, nor are the foundations of the Earth so secure At any rate the crust seems to heave up and down quite a lot

No sooner does land appear above the sea than it is attacked by all those destructive forces which its very presence has called to action, the process is what we call 'weathering' and the ultimate result is the disintegration of the rock and the removal of the debris In many parts of the world nature's dustbin is emptied every day In a few places it is never emptied But mostly it is being continuously emptied Not even the hardest rock is proof against weathering, and so relentless is the process that all land would long ago have been worn down and cast back into the sea — the ultimate salvage dump — were it not continuously being renewed by uplift The only part of the crust which is safe from demolition is that — much the greater

part — which has kept its original place at the bottom of the sea. The ocean basin floor, supporting and in turn protected by a mile or more of sea water, changes scarcely at all. So long as it is *under* the sea, the sea is its sure shield. Not till it breaks through into the air is it attacked by both sea and air.

When we approach the mouth of a great river from the open sea, say the Ganges or the Irrawaddy, we pass first from limpid blue sea to green sea. Then the water becomes less clear, loses its sparkle, becomes slightly turbid, then muddy. The low flat shore appears in the distance — at first it is difficult to distinguish land from sea. Gradually the outline becomes firmer, trees appear. What we have seen is the debris from the weathering of the land being carried out to sea to be deposited on the continental shelf layer by layer. Almost all the sedimentary rocks which form so much of the visible land were thus laid down.

It might perhaps be thought that the entire ocean floor would presently be covered with sediments derived from the weathering of the land. Rivers like the Amazon, the Mississippi and the Ganges carry enormous loads of mud out to sea, but inspection shows that the sea is clear of all visible traces of mud at a distance of two or three hundred miles from the mouth of the largest river. As a matter of fact the mud is probably all deposited within 250 miles of the coast, in the shallow water which covers the continental shelf. Apart from wind-blown dust, floating bergs, volcanic explosions and ocean currents impregnated with mud, there is no means by which the debris of the land surface can be carried far out to sea, and the deep ocean basins know nothing of land sediments; unless indeed continents once existed there and have since been sunk without trace. There is little warrant for these lost continents on the scale sometimes demanded by naturalists, though certain land-bridges probably existed.

A distinction then must be drawn between crust which has lain permanently in place under the deep sea, and land crust. The deep sea crust consisting mainly of granite is the original

lithosphere; the land crust — that part of it which is stratified at any rate — has been derived from the materials of the original crust at second, or third, or fourth hand; the same rocks being demolished again and again, to be reconstructed out of the wreckage. Most of the rocks we see around us therefore give only a dim clue to the composition, still less the structure, of the original crust. Nor can we know very much about the interior of the deep sea floor. Nevertheless, there are some very ancient land surfaces in existence which have never been under the sea since they were first raised up and which therefore have never been overlaid by sedimentary rocks. These might give a clue to the appearance of the original crust. Further we get a hint of the fresh interior of the crust in the outpourings of volcanoes. It would seem that the original crust may have been something like lava or basalt. But the ocean floor seems to be composed chiefly of granite; it is the continental blocks whose foundations are of basalt.

The geographer need not pursue these matters. He will accept what geologists and other specialists hand out to him; or should one say select from the rival theories! Let us therefore suppose that the Earth's crust forms a more or less continuous shell over the hot core, punctured here and there by volcanic vents; further, that certain regions of slightly different composition have for a very long time been thrust up above sea-level and so come into contact with the atmosphere.

Do the ocean basins and the continental platforms date from the very beginning? Was the hydrosphere never complete? Here we are back in the realm of controversy. It may, however, be said that there is more reason for believing that the ocean basins have always been where they are than for believing that the continental platforms have always been continents, at least in their present form. One difficulty is that if the continents have always existed, though not in their present positions, they must have been somewhere else; and that rather vitiates the argument that the ocean basins have always been ocean basins.

The forces necessary to uplift or buckle the cooling crust were derived from the hot interior core, which, unaided, appears to have caused the first bucklings. Later another force came into operation, namely, the weight of sediment, worn from the face of the land, and carried away by rivers to be piled up elsewhere. This ever-shifting load must have put considerable strain on the crust, especially at weak spots. No sooner was equilibrium, disturbed by the buckling of the crust, re-established than it was again upset by a gradual redistribution of load over the foundations. Countless millions of tons of rock have, in the course of ages, been removed from here, piled up there; and the crust has reacted. In places one finds strata many thousands of feet thick which have certainly been laid down continuously in shallow water — say a hundred fathoms or less. This would only be possible if the sea floor sank steadily under the increasing weight of the load, thus keeping pace with the deposits. In the Assam Valley there are 3000 feet of silt, which certainly was not laid down in 500 fathoms of water; it bears all the signs of having been deposited in a very shallow sea.

Evidently the crust of the Earth is more flexible than it appears to be. Sometimes it has broken under the strain, as the fractured ends of the buckled strata, generally 'faulted', prove. The fact that strata can be uplifted from the sea bed, bending but not cracking, also shows that the crust is not completely rigid.

Quite lately in geological time another redistribution of load over a part of the Earth's crust has taken place — I refer to the glacial age when an enormous weight of ice rested on the land surface of the northern hemisphere. It has been calculated that the weight of ice supported by the plateau of Tibet alone amounted to billions of tons.[1]

When the final thaw came this weight was lifted from Tibet, and shifted as water back to the sea, to be redistributed over the ocean basins. But it took with it probably an even greater weight of mud, ground from the rocks, and deposited it in the Bay of

[1] 'The Deglaciation of Tibet', *Geological Magazine*, 1929

Bengal at a distance of only 800 miles from the area of origin.

Lakes and rivers form the visible part of the hydrosphere intimately connected with the land surface; there is further an invisible part — also land-based — invisible because circulating underground.

Invisible land-based water is of two kinds, meteoric water as it is called, comprising running streams derived from percolating water which came originally from the sky; and deep-seated, or plutonic water, more intimately combined with the crust, which becomes visible only in geysers and hot springs, and manifests itself even more plainly in volcanic explosions.

The shallow-lying meteoric water derives from atmospheric rain or snow, and is always being renewed. It reaches the surface as springs. Plutonic water, the real crustal water, has apparently always been there. It was bound up with the rock at the time of its formation. It is not renewed from the atmosphere, and is slowly being used up by being freed from chemical or physical combination, unless possibly it is renewed from the sea. Thus it does not belong to the hydrosphere; it is part of the crust, until released.

Yet another facet of the hydrosphere is water vapour, which penetrates and diffuses itself through the atmosphere to become visible again, sooner or later, as dew, mist, cloud, rain, frost or snow and to be returned to earth. Thus there is an ever-revolving cycle of water passing from hydrosphere to atmosphere (evaporation), from atmosphere to Earth (precipitation, after circulating in the atmosphere) and back again to the atmosphere by evaporation.

Though land may be regarded as crust misplaced, separating, over a limited area, the hydrosphere from the atmosphere, the separation is, as we have just seen, imperfect. It is not watertight. Sea and air play major parts in the cycle described above. If there were no land the cycle would still revolve. But more slowly. The land in fact plays a very important part — it is like what chemists call a catalytic agent, stepping-up by its mere presence the interaction of the principals.

In proportion to area, far more rain and snow falls on the land surface than on the sea, and the only result, at least the most important result, of this dislocation of the crust has been to call down on the land a vast amount of water which would not otherwise have been in circulation. The water flows over the land surface as rivers, or more slowly as glaciers, fills hollows to form lakes, lies on the surface as snow, dew or frost, and is all the time evaporating into the atmosphere, percolating through the upper layers of the crust, as well as flowing back to the sea whence it was derived. An enormous amount of water is evaporated from the land surface, from rivers as well as from lakes. It has been calculated that only 6 per cent of the rainfall of Australia goes back to the sea; most of the remaining 94 per cent is evaporated before it can reach the sea. Rivers like the Yangtze, Mekong and Salween, which flow for hundreds of miles through the hot arid gorges of Eastern Tibet, must lose a vast quantity of water from evaporation. So also the Nile. The Tarim, after reaching a maximum size, dwindles and disappears in the desert as a result of percolation and evaporation, though much of its water is drawn off first for irrigation. In the cold thin atmosphere of dry Tibet snow evaporates without melting, and rivers like the Tsangpo also evaporate rapidly, because of low atmospheric pressure at high altitudes.

It thus appears that the insulation of the three shells is not so complete as at first sight it appears to be. Apart from irregularities resulting from the reversal of the normal sequence, gaseous shell, liquid shell, solid shell, there is a good deal of inter-penetration at the surface, wherever the shells come into contact; and of course, as we have seen, they are in contact over large surfaces, land and sea, air and sea, land and air; not to mention crust and sea.

And here perhaps I might point out that a good deal of the land surface — about 10 million square miles in fact, is regarded by geographers as being now submerged, though not permanently submerged, beneath the sea. This drowned land is called

Bengal at a distance of only 800 miles from the area of origin

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Invisible land based water is of two kinds, meteoric water as it is called, comprising running streams derived from percolating water which came originally from the sky, and deep-seated, or plutonic water, more intimately combined with the crust, which becomes visible only in geysers and hot springs, and manifests itself even more plainly in volcanic explosions

The shallow lying meteoric water derives from atmospheric rain or snow, and is always being renewed It reaches the surface as springs Plutonic water, the real crustal water, has apparently always been there It was bound up with the rock at the time of its formation It is not renewed from the atmosphere, and is slowly being used up by being freed from chemical or physical combination, unless possibly it is renewed from the sea. Thus it does not belong to the hydrosphere, it is part of the crust, until released

Yet another facet of the hydrosphere is water vapour, which penetrates and diffuses itself through the atmosphere to become visible again, sooner or later, as dew, mist, cloud, rain, frost or snow and to be returned to earth Thus there is an ever-revolving cycle of water passing from hydrosphere to atmosphere (evaporation), from atmosphere to Earth (precipitation, after circulating in the atmosphere) and back again to the atmosphere by evaporation

Though land may be regarded as crust misplaced, separating, over a limited area, the hydrosphere from the atmosphere, the separation is, as we have just seen, imperfect It is not water tight Sea and air play major parts in the cycle described above If there were no land the cycle would still revolve But more slowly The land in fact plays a very important part — it is like what chemists call a catalytic agent, stepping-up by its mere presence the interaction of the principals

In proportion to area, far more rain and snow falls on the land surface than on the sea, and the only result, at least the most important result, of this dislocation of the crust has been to call down on the land a vast amount of water which would not otherwise have been in circulation. The water flows over the land surface as rivers, or more slowly as glaciers, fills hollows to form lakes, lies on the surface as snow, dew or frost, and is all the time evaporating into the atmosphere, percolating through the upper layers of the crust, as well as flowing back to the sea whence it was derived. An enormous amount of water is evaporated from the land surface, from rivers as well as from lakes. It has been calculated that only 6 per cent of the rainfall of Australia goes back to the sea; most of the remaining 94 per cent is evaporated before it can reach the sea. Rivers like the Yangtze, Mekong and Salween, which flow for hundreds of miles through the hot arid gorges of Eastern Tibet, must lose a vast quantity of water from evaporation. So also the Nile. The Tarim, after reaching a maximum size, dwindles and disappears in the desert as a result of percolation and evaporation, though much of its water is drawn off first for irrigation. In the cold thin atmosphere of dry Tibet snow evaporates without melting, and rivers like the Tsangpo also evaporate rapidly, because of low atmospheric pressure at high altitudes.

It thus appears that the insulation of the three shells is not so complete as at first sight it appears to be. Apart from irregularities resulting from the reversal of the normal sequence, gaseous shell, liquid shell, solid shell, there is a good deal of inter-penetration at the surface, wherever the shells come into contact; and of course, as we have seen, they are in contact over large surfaces, land and sea, air and sea, land and air; not to mention crust and sea.

And here perhaps I might point out that a good deal of the land surface — about 10 million square miles in fact, is regarded by geographers as being now submerged, though not permanently submerged, beneath the sea. This drowned land is called

the continental shelf, and it marks the edge of the platform on which the continental land is built It juts out from the visible land surface for a varying distance to the brink of the oceanic basins, and is covered by a shallow sea not much more than 100 fathoms deep and often much less Where a continent presents to the ocean a wide coastal plain, the submarine slope is usually gentle, and it is difficult to say where the land ends or when the edge of the basin is reached, the distinction indeed becomes arbitrary, and is conveniently drawn at the 100-fathoms line But where the continental land rises steeply from the ocean, as along the eastern margin of the Pacific, the shelf or platform is very narrow, sloping steeply for a short distance to plunge suddenly down to profound depths The shelf is also a region of deposition, where rivers drop their silt, which sooner or later will be uplifted in the form of stratified rocks above sea level Such regions of deposition have frequently been upraised in the past, as is proved by their shallow sea fossils

These facts suggest that there is too much sea It more than fills the great basins originally designed to contain it, and overflows, spilling on to the edge of the land Does this mean that originally the sea no more than just filled its basins — that land was land and sea was sea and never the twain should meet, or rather encroach upon one another's preserves? It might, but there is no proof that it does If more crust were to be pushed up above sea level it must displace water, and the sea level would rise in its basin and advance over any flat land lying close to sea level During the Mesozoic era the whole of the Tibet plateau and the Himalaya were under the sea, the elevation of so great an area must have displaced a lot of water, and the brimming basins may well have overflowed

After the final solidification of the crust, with the separation of sea and land, the sea may have just filled its basin, no more But during the thousands of millions of years which have elapsed since then, an enormous quantity of water must have been released, from chemical and physical combination with

the crust, and added to the sea. There is probably more sea now than there was originally. This may easily have caused the sea to encroach on the land.

During the recent ice-age an immense amount of water was extracted from the ocean and fixed as solid ice, which for tens of thousands of years continued to increase, thereby lowering the level of the ocean and exposing crust hitherto submerged. When the ice melted, the water returned to the sea (together with a great deal of land) and the sea-level rose. This cycle of change happened several times during the Pleistocene glaciation.

But we must not forget that the entire land surface could be sunk beneath the sea, leaving a complete hydrosphere two miles deep covering the globe. It hardly looks as though the sea were designed to fill the basins only; and we come back again to the suggestion already put forward, that land is a bit of a fluke.

The total visible land area of the globe is about 56½ million square miles against 141½ million square miles of sea. Adding 10 million square miles of submerged land, we get a total of 66 million square miles for the continental platforms, against 141 million square miles of sea, including overlap, or 131 million square miles of oceanic basin; almost exactly double the area of the land blocks.

To return then to the sea-air-land contacts, and the creep of one sphere into the other over the area of contact. That a gas, even under so little pressure as 14 lbs. to the square inch, which is the weight of the atmosphere at sea-level, should interpenetrate a liquid is hardly surprising; and we are all familiar with the fact that oxygen is in fact dissolved in river and sea water and that fish absorb this oxygen through their gills. Neither is it surprising that a liquid should leak through a solid as loosely compacted as much of the land surface is, since a shower of rain can be seen to percolate rapidly through the Earth. Meteoric water in the shallow strata of the Earth's land surface is easily accounted for; in alpine regions of heavy

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demolition and little transport, one can often follow the course of underground drainage for a considerable distance What is surprising is the amount of plutonic water hidden inside the earth's crust, nay, combined with it, the great depths at which it often occurs, and the tenacity with which it is held in combination

That some water should percolate through the bed and banks of a river seems natural enough, it is less easy perhaps to imagine the sea percolating through the ocean floor

Perhaps percolation is the wrong word here The water does not seep through in response to gravity, as rain seeps through sand, but as a result of enormous pressure, so enormous a pressure, beneath two miles of water, that however compact the floor may be, *some* water will be squeezed through The surface is least compact on the submerged shelf, where silt is being deposited, that is to say outside the ocean basin, especially close inshore, though here the pressure is not great Twice every twelve hours it is reduced, and in the intertidal zone very considerably reduced, as the tidal wave recedes, leaving the zone in contact with the atmosphere At the same time the pressure is slightly increased where the waters are heaped up in mid-ocean This fluctuative pressure may help to force water through the floor into the crust, and perhaps accounts for the presence of plutonic water in rocks now far above sea-level But most plutonic water, whether free or combined, has doubtless been there from the beginning — it is built into the structure of the crust It fills microscopic pores in such rocks as quartz (e g milky quartz) or it is combined as water of crystallization in many common rock forming minerals Where it occurs free it has separated out from combination

Plutonic water manifests itself in volcanic explosions which are partly if not entirely caused by its sudden conversion into steam, the vast cloud of condensed vapour ('steam') hanging over a volcano in eruption is well known. Darkened by volcanic dust, it forms the familiar 'smoke' Geysers and hot springs, found in volcanic regions, draw their water from

plutonic sources deep down; while free plutonic water is sometimes tapped by deep borings, as in South Australia and Queensland, where it is not easily distinguished from artesian water. Even if there were no land, there would still be plutonic water in the Earth's crust.

Though the atmosphere freely penetrates the hydrosphere, its slight pressure is insufficient to force it into the lithosphere. There is plenty of gas held within the crust, but that again is to be reckoned as part of the crust just as plutonic water is part of the crust; it has nothing to do with the atmosphere, until it is released through fumaroles, volcanic vents and hot water into the atmosphere. Thus, though they are in contact, the atmosphere hardly penetrates the land surface, except to a depth of a few feet, where the surface rock is covered with loose soil or sand, or where earthworms are constantly churning the top spit. Also, where there is a heavy cover of vegetation, roots, thrusting aside the soil particles, may allow a certain amount of air to penetrate. Good aeration of the soil is one of the prerequisites for the health of most plants. But the root hairs through which plants draw their nourishment from the soil are surrounded by a film of water rather than of air. We may safely say then that nowhere does the atmosphere penetrate the land surface, even where porous limestone or lava strata outcrop, to a depth of 100 feet.

On the other hand the crust penetrates the atmosphere, as dust, to a height of several miles. But atmosphere in contact with land — that is crust — is not the normal sequence. The normal sequence is, as we know, gaseous shell or atmosphere, enclosing liquid shell or hydrosphere, enclosing solid shell or crust, which finally encloses the core of the Earth. And in this normal sequence the atmosphere does penetrate the hydrosphere to a depth of half a mile or more, and the hydrosphere does penetrate the lithosphere, to a greater or less extent, though not to the same extent everywhere. Water, however, is also a *constituent* of the lithosphere, at much greater depths than is reached by meteoric water, and independently of it.

Conversely the hydrosphere, in the form of vapour, penetrates far into the atmosphere to reappear as cloud, which at 30,000 feet may be composed of solid ice-crystals. Above 30,000 feet there is neither water vapour nor dust. Finally the lithosphere, in solution or in suspension, interpenetrates the hydrosphere everywhere, although it is almost entirely owing to the presence of a land surface that it does so. If there were no land surface the sea might still be salt: this is by no means certain; but it would never be turbid. The effect of submarine volcanic explosions would be local and brief.

Thus, though the interpenetration of the three shells is relatively minute compared with the thickness of each, so that air, sea and crust appear as three separate and distinct envelopes one inside the other and all wrapped round the core of the Earth, nevertheless, it is this short penetration and mingling which make life possible. Their significance to man is therefore obvious, and they deserve the closest study.

It will be appropriate therefore to devote the next chapter to a brief consideration of life on the Earth's surface.

III

THE FILM OF LIFE

No branch of science lies entirely outside the scope of the geographer. The botanist, the zoologist, the geologist, the archaeologist all have something to tell him about the variety, migrations and distribution of life (including man) in space and time. Here, however, we are only concerned to take an all-round glance at life on the Earth, noting certain peculiarities in its distribution. I shall therefore confine myself to a broad statement of the part life in general plays in the three-dimensional world of the modern geographer.

The most obvious fact in the world is of course Life, and the highest expression of Life is Man. Life probably originated in the warm seas; even if all the land were to disappear, life would still continue in the sea. It is of course possible that it existed in the sea before land appeared. But there could have been no life in the atmosphere before land appeared.

Now life as the scientist knows it is associated only with protoplasm; as soon as protoplasm ceases to include life it ceases to be protoplasm. It is then no more than jelly. This stuff called protoplasm is a complex compound which has a definite chemical composition, definite but elusive properties, and definite limitations. It can exist only under certain definite physical conditions, between certain temperature limits, and only in the presence of oxygen. It is indifferent to darkness, but ordinarily far from indifferent to drought. It may be noted, however, that while life normally exists only between comparatively narrow limits of temperature pressure and so forth, it is at the same time adaptable. Occasionally the normal limits are relaxed, and we find it existing, highly protected, under strange conditions. Thus fish have been brought up from over a mile below the sea's surface; fungus spores have been found floating in the stratosphere 7 miles above the Earth,

and have germinated. Animals, usually blind, live in the perpetual darkness of caves deep within the Earth, plants survive high temperatures in hot springs. One has only to consider the conditions a mile below the surface of the sea — a pressure of 1 ton per square inch, a temperature approaching freezing point, utter darkness — to realize that life can, on occasion, face fearful odds.

On the other hand a little more, or a little less, ozone in the atmosphere might cause its utter destruction, or at any rate man's destruction. With more ozone, fewer ultra-violet light rays would reach us, and we would almost certainly die out for lack of vitamin D. We might even be pushed out by the enormous bacterial growth which would result. With less ozone, too much ultra-violet light would get through, and our skins would be burnt up.

On such precarious chances does life on Earth uneasily depend.

In the absence of sufficient moisture it dies, unless it can shut itself up in a thick cellulose pill-box against just such an emergency for some time; and it is stable — here is the paradox — just so long as it is continuously changing. Its molecule is enormous — as molecules go. From the above, it would not seem that protoplasm is a particularly delicate substance. Under favourable conditions it appears to be immortal. Whether it be immortal or not, however, scientific men incline to believe that it has hitherto cropped up on no other planet than this Earth, and that its appearance even here was rather in the nature of a fluke. It could hardly be called inevitable. Of that, however, we know nothing, and it is perhaps idle, though entrancing, to speculate.

However that may be, by chance or by design life appeared. It may disappear — indeed, if the gloomy forecasts of some astronomers as to the ultimate fate of the Earth are correct, it must disappear; but the last rites will not take place yet awhile. In the meantime man's tenure of the Earth, in spite of his ignorance and folly, seems secure. The physical world is of

course far older than life it may indefinitely outlive life But such speculations do not fall within the scope of geography, which deals with earth processes in relation to man What the geographer asks is What are the minimum conditions for life and how much of the Earth fulfils those conditions?

Most of us are more familiar with life on land than with life in the sea or even in the air The land surface is part of the Earth's crust, which has been pushed up through the hydrosphere This displacement of the crust has had some surprising results, it has revolutionized life, culminating in Man as its highest expression Before the emergence of land, life was confined to the sea, but there may have been land for millions of years before it could support life

Now fluids like water and air are easy to penetrate and to move about in, solids like land are not Life on land is almost entirely confined to the surface Earthworms, spiders, beetles and other small fry, including mammals, burrow a few inches or a few feet into the earth, but nothing to speak of, the limit is soon reached It is certain that there is no life, probably not even bacterial life, a quarter of a mile below the surface For one thing there is probably no oxygen at such a depth, though not all bacteria need oxygen [1] True, there is a certain amount of cave life, but that is different, here there is no lack of oxygen, because caves are directly in touch with the open air In fact caves may be considered part of the surface, roofed over Their chief peculiarity is perpetual darkness

So much for the land There is abundant land life, but it is confined to two dimensions When we come to life in the atmosphere and in the hydrosphere, things are somewhat different

Life exists in the sea just so far down as there is oxygen to sustain it There is plenty of life half a mile and even one mile down, but perhaps not much lower than that At depths of two miles or more there is almost certainly none, not only because of lack of oxygen but also because of the enormous pressure at

[1] Anaerobic bacteria are an exception to the rule that oxygen is necessary to life

and have germinated. Animals, usually blind, live in the perpetual darkness of caves deep within the Earth, plants survive high temperatures in hot springs. One has only to consider the conditions a mile below the surface of the sea — a pressure of 1 ton per square inch, a temperature approaching freezing point, utter darkness — to realize that life can, on occasion, face fearful odds.

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Although it was the last of the three shells to be invaded, he atmosphere is nevertheless in a literal as well as in a metahorical sense the very breath of life everywhere. Or rather he oxygen in it is. Whether on the land surface or under it, or in, on, or under the hydrosphere, it is the oxygen of the air that permits life to function and be itself. Life, we believe, began in the middle shell, in the sea, between the crust and the atmosphere. Then, when the crust was buckled so that parts of it were uplifted and came into direct contact with the atmosphere, life followed, crawled out of the sea on to the land, and, finding oxygen a good deal more plentiful there, went ahead. Finally life occupied the outermost shell, the atmosphere itself. Nevertheless, though life has invaded all three shells, it is permanent in two only, namely hydrosphere and atmosphere — though most of the atmosphere life lives on the lithosphere surface. Such life as lives above the lithosphere must come to earth or perish. Of course, oxygen occurs in other places besides the atmosphere, but not free. It helps to make the hydrosphere — water is a compound of oxygen and hydrogen — and is abundant in the crust, in combination with silicon, iron and other elements. But as such it is not available to life, as it is in the atmosphere. Even in the sea it is the *dissolved* oxygen which fish absorb.

It comes to this: that although life has adapted itself to some extent to all three shells, atmosphere, hydrosphere and lithosphere, or air, sea and land, and although it can be detected at possibly two miles below the surface of the sea and eight miles above it, nevertheless, in actual practice life hardly strays beyond the irregularities of the continental

that depth. Two miles is about the average depth of the ocean basins, so that if there is no life below that depth, a large area of the ocean floor — that is, of the crust surface — is desert. At whatever depth life ceases, the fact remains it is far more abundant on the coastal shelf than in the basin, except close to the surface, where, as microscopic life, it is most prolific, including both animals and plants.

As to the ocean of air, the depth (or height) of which may be 20 or 30 miles, but is probably less, it is certain that life does not penetrate to great heights, though the spores of fungi have been collected about seven miles up. Here we are dealing with small pressures. At the very bottom of the air ocean, that is to say, on the Earth's surface at sea-level, the pressure is only 14 lbs. to the square inch. Most of the life of the Earth's surface lives at or near the bottom of the air ocean. But some life lives mainly in the atmosphere, though it is land-based. Just as lack of oxygen and perhaps increased pressure finally put a limit to life in the depth of the hydrosphere, so lack of oxygen and moisture and increased cold soon put a limit to life in the height of the atmosphere. Life, in fact, though capable of penetrating the two fluid shells, soon comes up against conditions beyond its tolerance. It can survive in the atmosphere — not permanently, but for a time — at heights greater than the depths at which it can survive in the sea, both measurements being made from sea-level. In fact, it can probably survive at heights equal to the highest mountains in the world, at least so long as it is in touch with those mountains. There is life *on the Earth* at 20,000 feet altitude; and we might put the normal imit at 30,000 feet — though one would not expect to find any ife at 30,000 feet over the Pacific Ocean unless it had been arried there unresisting. Spores, such as ferns and fungi roduce, might be carried to such a height by air currents, and urvive; but it is hardly an economic level.[1] Birds, insects,

[1] Capt Albert W. Stevens and Capt. Orvil A Anderson, of the U.S Army ir Corps, on their record stratosphere flight, 1935, found fungus spores at miles

pollen, wind-borne fruits and seeds, spores, bacteria even, might reach 30,000 feet over the great mountain ranges of the world, such as the Andes and the Himalayas, but it cannot be said that life is commonly met with in the atmosphere at a height of $5\frac{1}{2}$ miles; 3 miles is more usual, and there is not much life even at 15,000-16,000 feet, except close to land which is itself 16,000 feet above sea-level.

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where the sea has overflowed it 100 fathoms deep to the crests of the highest peaks some 29,000 feet above sea-level. The condor soars higher than the snow-capped peaks of the Andes, and birds wing their way over the Himalayan giants. Spiders have been reported on Mount Everest at over 21,000 feet – *though they had perhaps lost their way. Flowering plants* bloom magnificently at 18,000 feet in Tibet, and lichens might perhaps be found at any altitude where rocks are exposed. Even butterflies brave a rarefied atmosphere in the mountains. But beyond the tops of the highest mountains, as below the 1200-fathom line, life hardly exists; that is to say, Life forms a film some seven miles thick which clings close to the surface of the Earth.

The three outer shells of the Earth have a combined thickness of perhaps 50 miles; hence the film of life occupies about 1/7th of the total thickness of the combined outer shell And lest that should seem too secure a footing, it is as well to remember that it amounts to about 1/550th of the thickness of the Earth, measured from the surface of the atmosphere to the centre of the core.

Man himself is much more limited, for he is confined to 1/4th of the surface, and can hardly sustain himself over more than 6/7ths of that quarter; the remaining 1/7th of the land is more or less desert, or otherwise uninhabitable.

Thus it would seem that Life in general, and Man in particular, have after all but a precarious footing on the Earth's surface. But it would also seem that so long as Life survives, Man, though confined to the land surface, will hold his own. One thing is certain. As the world is to-day, and for as long as we can foresee, only Man can destroy Man. Before going on to discuss climate, let us examine Man in the mass, as Population.

MAN AND POPULATION

THE distribution and numbers of population are of great concern to the geographer because of the strides man has made and will continue to make in bringing the Earth under control. It is fairly certain that he will effect as great changes on the face of the Earth in the twenty-first century as he was able to effect in the previous twenty centuries, or even probably in the last 5000 years. By destroying forests, irrigating deserts, diverting or stemming rivers, draining swamps, flooding basins, digging canals, ploughing and cultivating plains by mining and boring holes in the crust to draw out oil, brine, water, building cities and roads, and by many other activities, man is profoundly altering his environment and affecting his own future; not necessarily for the worse. Each separate effort may seem puny; it is the cumulative effect which is felt. For climate itself is gradually being altered, at least locally. But of all these varied activities, that of recklessly destroying forests, especially in the mountains, is the one he may have most cause to rue.

If another period of intense cold is on the way, creeping over the northern hemisphere, modern man has his escape routes, planned and ready, the tropical belt organized to receive him. It will not again catch him unprepared.

Nor does the present distribution and concentration of mankind give a clue to where a fever of activity may next break out. It is so easy a matter nowadays to move whole populations to almost any part of the world — at least so far as the mere transportation problem is concerned — that, were oil to be located in the jungle heart of Brazil or gold to be discovered in the frozen wastes of Antarctica, there would be no shortage of men to work those fields. But the present geographical distribution of mankind is not without significance.

Down to 1940, at any rate, there is no reason to suppose that

the Earth did not yield enough to feed every man, woman and child, if not lavishly, at least adequately. The fact that millions often did not have enough food to keep them in good health can only be ascribed to inequality of production in densely and sparsely-populated regions and to inadequate communications. There were surplus areas and deficiency areas. Surplus food was rarely in the right place at the right time; and since food does not keep, it was wasted.

Most of us are accustomed to 'crowds'. We see almost endless processions of people trooping to and from the daily grind in our cities, crowds at football matches and race meetings, crowds listening to political speeches and, for the time being, marching armies of men and women. So accustomed are we to seeing these great mobs of people that it becomes increasingly difficult for us to realize that the land is not everywhere thickly populated; increasingly difficult to picture vast regions where the population is sparse — 16 (or fewer) to the square mile, or one person to every 40 acres — still less the huge spaces, amounting to several million square miles, of desert and tundra, where the average density is less than one person per square mile, where hundreds of thousands of square miles are completely devoid of human beings, and where one can walk for untold miles, indeed, for days and days without meeting one solitary person or one single human habitation. Though this is difficult to picture, such is the fact.

great river deltas of South-East Asia; the Ganges valley and Bengal; the industrial regions of the Western European states; and the industrial regions of the Atlantic states of America. Yet even after writing off 5½ million square miles of land as absolutely uninhabitable, we are still left with enough good land to supply every person in the world with about 15 acres! Why then this overcrowding?

But how misleading are averages! If any reasonable inference can be drawn from the above average it is this: that the world is not yet over-populated. However, it is doubtful whether one is justified in drawing even that inference from an average which has so little relation to stark reality, yet for what they are worth the figures are not without interest. Perhaps the real answer is that man is a gregarious and co-operative animal.

If we look at a population map of the world, we can see at a glance what the distribution really is. We see a few small densely-populated areas as described above, considerable areas well populated, the population evenly distributed, and vast areas sparsely populated or uninhabited. The location of the densely-populated areas in Europe, Asia and North America have been mentioned. The thinly-populated areas — and some of them are *very* thinly populated, averaging perhaps five persons to the square mile, or even unpopulated — comprise three different types of country, namely (i) desert and near-desert including tundra, (ii) mountains and (iii) jungles. The densely-populated areas comprise chiefly the great plains and river deltas, with their cities and heavy industries close to the main sources of basic raw materials.

The well-populated areas comprise fertile valleys and plains, mostly along big rivers, but sometimes along coasts. Desert and near-desert are amongst the most sparsely-populated regions in the world, and considerable areas of every great desert tract are uninhabited. Some of them never have been inhabited; others were formerly inhabited but have been rendered uninhabitable by deforestation, by neglect of irrigation, by change of climate, or by war, pestilence and famine.

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Apart from a few comparatively insignificant areas — dots on the globe — there are only six regions in the world, and those for the most part scattered, which are *densely* populated. These six regions are situated in Japan, China, South-East Asia, India, Western Europe, and eastern North America; leaving by far the greater part of the land world and the whole of the southern hemisphere very sparsely populated indeed. Assuming a total world population of 2000 millions (which is perhaps rather high), about 1/3rd is concentrated in the six regions indicated above, comprising industrial Japan; North-East China, the Yangtze estuary and the Canton delta; Annam and the three

great river deltas of South-East Asia; the Ganges valley and Bengal; the industrial regions of the Western European states; and the industrial regions of the Atlantic states of America. Yet even after writing off 5½ million square miles of land as absolutely uninhabitable, we are still left with enough good land to supply every person in the world with about 15 acres! Why then this overcrowding?

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Mountainous regions, though not necessarily uninhabited, are difficult to cultivate and so as compared with plains are always sparsely populated Moreover, mountain climates are suitable for few crops, and an altitude is soon reached at which *no* crops will ripen In North Burma the limit of cultivation is about 7000 feet In Europe it is considerably lower Thus in the greatest mountain ranges, such as the Andes and the Himalayas, very large areas are entirely uninhabited Yet it is certain that they can be made habitable, certain that they will attract population in the future

Mountains, if arid, are rocky and inhospitable, without soil, as for instance the mountains of Arabia Moreover, such mountains being waterless it is impossible to raise crops, irrigation is out of the question If, on the other hand, they lie in the track of moist currents like the southern slopes of the Eastern Himalayas, the New Zealand Alps, the eastern slopes of the Andes, and New Guinea, they receive too heavy a rain fall and are covered with dense forest Before cultivation is possible, the forest must be destroyed, and one result of that is all too frequently to start erosion of the soil, ending up with bare rock, till finally nothing at all will grow This is what is happening to-day in North Burma

Dense tropical jungles such as we see in the Congo and Amazon basins and in New Guinea on a large scale, and in the Sunderbans of Bengal, in Sumatra, in Queensland, in Guiana and many other places on a smaller scale are generally very sparsely populated, if not uninhabited Evergreen jungle on the plains usually denotes a water table only a foot or two below the surface, as in Bengal Irrigation even during the long dry season is unnecessary, but at flood season the ground is often waterlogged or actually flooded, as thousands of square miles of the Amazon valley are annually flooded

During the last millennium a huge area of tropical jungle has been destroyed, to make way for crops and no doubt more will be destroyed yet But perhaps the limit of good agricultural plains land has been very nearly reached, and as much is being

lost each year as is being gained. New centres of population are likely to strike root in the mountains, especially in those regions where the rainfall is moderate.

It would be a mistake to imagine that all deserts can be irrigated. Such structures as the Great Boulder Dam, the Lloyd Barrage, Assouan and many others show what man can do in the way of irrigation. No doubt on the thickly-populated tropical and sub-tropical plains where the individual holdings are small or where, as is more likely, near-serfs work for absent landlords, the peasant never gets quite enough to eat. So irrigation plans are drawn up and a resounding campaign to grow more food is launched. Nevertheless, to raise more rice amongst a peasant population of rice-eaters, or more wheat amongst wheat-eaters, will almost certainly result in an increase in the number of mouths to be fed, and *not* in any rise in the standard of living. Only when each peasant is assured of something in exchange for his surplus does the standard of living rise slowly. Usually the actual growers get no more than a fraction of the exchange value.

People talk lightly of industrializing the East. But you cannot industrialize a country, especially a country the size of India, overnight. At present India can barely feed herself, although 90 per cent of her population are peasants. Where then will the millions of workers, contemplated by the proposed greater industrialization of the East, live? or more exactly, how are they going to be fed? Not by importing food from countries which are themselves being industrialized. Malaya, one of the most fertile regions in the world, raises only 40 per cent of its food supply, so highly industrialized is it. The same is true of Ceylon. That appears to be a problem which the captains of industry-to-be refuse to contemplate. They leave it perhaps to solve itself when the time comes; and that is just what the advocates of a planned world economy cannot tolerate. On the other hand a gradual industrialization might be beneficial. But the truth is, industrialization is not for everybody. It depends upon many factors, including the

proximity of raw materials, transportation, access to markets and the type of labour available. Nor does it of itself automatically raise the standard of living, as European city dwellers have good reason to know.

But above all it depends upon the food supply; and that is limited.

Since geography is concerned with man's relationship to the Earth in all its manifestations, it is important that the geographer should know something about the numbers and distribution of human beings, as well as of other forms of life, with which he has at least something in common. But the combinations of man for social ends are not his concern. We have pointed out how unequally man is spread over the land surface, and how much of the land surface is hardly habitable. Attention has been drawn to the tireless activities of man in altering the surface; and reclamation of the desert for living space has been touched on. Beyond that the geographer should not go, lest he involve himself in social questions with which, as a geographer, he is not concerned.

The population of the world is, as we have seen, very unevenly distributed, which is hardly surprising when we realize that 22 million square miles of the land surface, or approximately 40 per cent, are desert or near-desert. Large areas are apparently under-populated or over-populated; and war or peace may hang on such adjustments as may be possible. A good deal of misunderstanding exists, however, concerning under-population and over-population, and it is necessary to be quite clear what we mean by these terms. Before the question of adjustment can even be discussed, the population problem must be fully understood. In the end it turns on food supply and its distribution. According to Carr-Saunders,[1] about half the inhabitants of the Earth live on about 1/30th of its land surface, itself 1/4th of the total surface; so that half the world population lives on 1/120th of the world's surface; which gives us some idea of the habitable Earth. Narrow as it

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appears to be, this is a much more extensive distribution than that of any other of the higher forms of life.

To take a smaller area, more than half the population of Central Asia lives on less than 1/20th of its whole area (Penck). China's peasant civilization has enabled her to cultivate all available arable land to the limit. Yet 2/3rds of the total area of China supports only 1/6th of the population. In other words, 5/6ths of the population inhabits 1/3rd of the area.

If this too appears surprising, it may be stated further that of the 30 per cent of the land surface of the globe classed as cultivable, a considerable area is taken up by equatorial South America and equatorial Africa — the Amazon and Congo basins, which at present are densely-forested regions, and other considerable areas; by great mountain ranges like the Andes, Rockies and Himalayas, which are bound to be sparsely populated as compared with flat fertile deltas, or with flat, highly industrialized regions like Western Europe. Whether a population increases or falls depends on other factors besides good government. The Maoris of New Zealand are not increasing in numbers, neither are the Australian aborigines. Indeed, the latter are approaching extinction.

But as regards under-populated regions — are they then to remain under-populated? Or will the population of its own free will raise its efficiency so as to increase the habitability — if that is possible — and ultimately the population, of the region? Or must some outside race either openly as conquerors, or more subtly by infiltration, raise the efficiency of the local inhabitants? In other words, what fate awaits incorrigible muddlers? These are pertinent questions to which the geographer must try to find an answer. If he finds the answer, he must persuade the politicians to listen to him, since we are here dealing with practical matters of the greatest importance to the world. He probably won't succeed.

Now it is fairly obvious that if the solution of the under-populated region is possible, it will take a very long time to reach the maximum population. For example, it is estimated

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Now it is fairly obvious that if the solution of the under-populated region is possible, it will take a very long time to reach the maximum population. For example, it is estimated

that Australia could support a population of 25 millions (Some put it much higher) But at its present rate of increase of about 2 per cent per annum, it would take over 30 years to increase the population of Australia by one million

But not all sparsely populated regions *wish* to increase their population More probably most of them have never so much as given the matter a conscious thought

It is indeed unlikely that any country, prior to the twentieth century, has deliberately and for state reasons attempted to increase its population, as Western Europe has in recent years

Now the vast majority of human beings depend for their sustenance primarily on crops Fish, meat and so forth are of secondary importance, and meat in any case depends upon grazing Men must either raise crops — rice, wheat, barley, corn — or buy their grain and it appears that the area over which any crop can be successfully grown is small Since it is economically simpler to grow food than to buy it, the vast majority of mankind *must* occupy chiefly the favourable areas where crops can most easily be grown, and only secondarily those areas to which it can most easily be transported

But a large population which has to buy its food in exchange for service and goods rendered — that is a large industrial population — gains nothing by being favourably placed as regards a peasant population, unless the latter requires the service and goods offered, and is willing to raise a sufficient surplus of food in exchange Moreover, food, though by far the most important thing required by an industrial population, is not the only thing required It needs also raw materials These are points which are often lost sight of when people talk airily of industrializing vast regions like India and China, both of which will certainly have to feed themselves in the future, whether industrialized or not

Now whether a region is under or over populated depends upon other factors than the absolute number of human beings it contains It is not a question of the absolute number of

people per square mile, but of the absolute number of people it can support at a particular standard And this number again is not a fixed number, but varies with the standard of efficiency of the population Both North America and Australia may have been fully populated, or even over populated five centuries ago, but both are under populated to-day At the level at which the Amerindians and the Australian aborigines lived, these countries could probably never have supported larger populations than they actually did With the coming of more energetic, resourceful, skilful and, above all, informed people they could and do support far larger populations

Thus over and under population are relative terms Sparsely populated regions are not necessarily under populated regions, nor are densely populated regions necessarily over populated, although of course they may be

The ultimate test is, can the population which inhabits the region support itself? If it cannot, the region is over populated for that people at their standard of living It is obvious that by this test both India and China, or parts of them, in spite of a low standard of living, are grossly over populated Likewise, if a region is very sparsely populated it is not under populated so long as it can support no more at that standard It would be absurd to suggest that Arabia, for example, which has a population of about seven million, in an area of a million square miles, is under populated on the Arab standard

Nor is this the only point worthy of attention Population, though it turns ultimately on food supply, is not entirely governed by that A region may be over populated at a high level of efficiency but that condition will not necessarily persist through a further increase of population If the population is really efficient it will solve its problem Moreover, the question of fertility comes in Upon what fertility ultimately depends we do not know, but its results are clear With a falling birth rate — and the birth rate where examined, appears to be everywhere falling throughout the world — over population where it occurs may be no more than a temporary phase, which will

presently be succeeded by under population We must therefore be chary of calling a region over or under populated unless we are sure of our facts Still, we may be confident there are some regions of the world which are under- as well as some which are over populated

Tibet is a good example of a sparsely but probably not an under populated region The Tibetan government has no desire to see a more thickly populated Tibet, precisely because it would imply a complete revolution in the Tibetan way of life Is any nation going to insist that the Tibetans must step up their economy or become industrialized in order that more Tibetans per square mile may result — otherwise they themselves will occupy the vacant ground? Yet the only other way of increasing the population is by outsiders colonizing the empty land, as the Americans colonized the West

But, as already remarked, the mere fact that a more efficient people occupies a region is really no guarantee that it will actually support a larger population, though the conditions may be so improved that potentially it could do so The altered economy may be more than offset by a low fertility rate Nor can legislation increase the fertility rate Legislation, however, can temporarily increase the population in another way by lowering the death rate and increasing the expectation of life, as it has done in many countries This is equivalent to a partial population control, of which birth control is another aspect

Fertility is apt to vary with environment being highest in a peasant population living on the land where children, as soon as they can walk, directly contribute to the family budget and so earn their keep It is probably lowest, in the long run, in a highly industrialized city community where food is gained indirectly and children can only contribute to the family budget after a longer or shorter period of education Social legislation in the form of Factory Acts, compulsory education, raising the school leaving age, and so on tends to lower the birth rate and, together with the increased expectation of life due to greater

security, to alter the age groups. Fertility also seems to vary inversely with material prosperity.

No country will deliberately over-populate its territory. According to Carr-Saunders, large-scale migrations do not originate from regions of gross over-population, because the populations of overcrowded regions usually lack the energy and enterprise necessary for such movements. In fact over-population leads not to dynamic human eruptions but to indolence, lethargy and finally deterioration. History seems to bear this out. The peopling of the Americas and of Australia was not due to population pressure, nor did the Arab and Mongol invasions of Europe spring from over-populated regions.

An exception is afforded by Japan, which is probably somewhat over-populated. The result has been not internal weakness, but external aggression. Nevertheless, the Japanese failed to colonize two regions open to them, Manchuria and Korea, the former almost a vacuum.

Yet it is obvious that at any given time the world can only support a certain population. We cannot continue indefinitely to increase the population of sparsely-populated regions by industrialization or by any other means. The world's food must be grown somewhere; and when all the cultivable land in the world has been put under crops, only two possible means of increasing the food supply remain: (i) intensive cultivation, that is, raising more food per acre and (ii) rationing. This latter does not, of course, increase the food supply; it only makes the same amount go further.

Some millions of people, belonging to different stocks, live in the immense hill tracts of South-East Asia. We know nothing about the population trends of these numerous hill tribes beyond the fact that they have greatly increased in numbers during the last 50 years. But they cannot continue to increase at the same rate, or at any rate, without overflowing on to the already crowded plains.

In a monsoon climate and particularly in the mountains, the people are gripped in a narrow routine by two forces: (i) the

alternation of wet and dry seasons, (ii) the fact that the principal food supply is derived from annual crops If a tree grass such as bamboo were the chief crop, the advance of agriculture, stimulated by the necessity to treat the crop differently each year, might result in a considerable broadening of outlook As it is the people are bound by iron custom

The principal crop is maize, which is believed to have been introduced into Asia soon after the discovery of America, and may have reached the North-East Frontier of India before the end of the sixteenth century But the maize cultivated in North Burma at any rate belongs to a peculiar race, having a waxy endosperm

Professor C B Fawcett concludes that not more than 30 per cent of the land surface of the Earth is arable, even allowing for an increase of irrigation where this is possible, and he sums up that the land surface of the Earth comprises 40 per cent desert, 30 per cent arable, and 30 per cent various, including poor grazing land, forest and mountain This 30 per cent arable land — in round numbers 17 million square miles — is widely distributed over the Earth, hence the population also is unequally distributed

On the basis of these figures it would be possible to calculate the maximum food production of the world (allowing for the fact that some regions produce two and three crops a year) so that taking the minimum ration for each person, one could arrive at a rough estimate of the maximum population the world could carry Its distribution, of course, is quite another matter

From what has been said it seems that over populated countries like China and India are not likely to be a menace to anyone but themselves, and that the best way to draw the teeth of a truculent or aggressive people is to encourage it to increase its population to the maximum and beyond, as Britain has in fact encouraged India to do, innocently or rather, ignorantly

But against that comforting reflection must be set the undoubted fact that China and India are so vast, and contain

between them so large a share of the world's population, that if they were to collapse internally, it must affect the entire world.

Nor, indeed, can one derive satisfaction from the thought that Great Britain, with her declining birth-rate, though not over-populated, can hardly remain virile when her age groups are such that there are more over-sixties than under-forties in the population — which is likely to be her condition within a few decades.

And on that sombre note we may end the discussion of population and the habitable Earth.

V

CLIMATE

Everyone knows how climate differs in different parts of the world and in different parts of the country We speak of a tropical climate or a temperate climate or a continental climate or a maritime climate or an Arctic climate, and straightway conjure up visions of foreign countries, strange vegetation, dark or sallow skinned races To the geographer climate is of the utmost importance, it has profoundly influenced man's activities in the past, conditions his way of life in the present and may revolutionize his future Here, however, I propose to deal with it only in the most general terms, to show how it works and to demonstrate what an inconstant nymph it is, and how frequently it has altered in the past and *may alter in the future As to its direct effect on man, we know* little or nothing

Climate depends mainly on currents circulating in the two fluid shells which surround the solid Earth, that is to say, on air currents and ocean currents If there were no currents, there would be much less climate And if there were no land, there *would* be no currents, or only very feeble ones Once again we observe the dislocation of the Earth s crust which has brought air, land and sea into contact, producing momentous results

If the hydrosphere were continuous over the face of the Earth, if all the land were drowned, as it might so easily be, the world's climate would be far more uniform everywhere than it actually is During the geological period known as the Miocene, which came to an end some few millions of years ago, the Earth seems to have enjoyed a far steadier and more uniform climate than it has since the last ice age, and the geographer is tempted to suggest that there was more sea and

less land — much less land — in that far-off happy time. But it is doubtful whether his suggestion would be favourably received by geologists. There seem, in fact, to have been several periods in geological history — the Carboniferous or coal age is one — when for many millions of years the climate was curiously uniform over enormous areas, and the vegetation correspondingly similar over a large part of the Earth. And again the geographer whispers — could it have been that there was less land and more sea, a wider sea, in those days?

To leave speculation, if there were no land, climate would depend almost entirely upon latitude. The tropics would be hot, but not very hot, the poles cold, but not so cold as they are now. The change of temperature from equator to pole would be gradual and steady. Taking the mean annual temperature, the present temperature gradient between equator and pole is about 90° F. With a complete hydrosphere it might be as little as 50° F. or say the annual average range for London. Winds would be gentle, long continued and steady, ocean currents feeble. Rainfall would be scanty.

As soon as land appears, all this is changed. Violent currents are set up in air and sea, rainfall increases, temperatures reach higher and lower limits, and fluctuate more rapidly and with the increased activity everywhere the all-out assault on the land sets in.

What then is the reason?

Let us return for a moment to our supposed landless earth, round which both atmosphere and hydrosphere form complete shells, and are therefore everywhere in contact. Whatever energy the Earth receives from outside it receives from the Sun. The poles are cold because the sun's rays strike them at a low angle — and for six months on end they get no sunshine at all. The equator is warm because the sun's rays are vertical or nearly so throughout the year and the day always lasts for 12 hours. When land appears, the Earth still derives its energy from the sun, which now warms air, sea and land.

But not equally. As physicists put it, water has the highest

specific heat of any known substance. The same sun warms the rocks quickly, the water more slowly. On the other hand, once the water *is* warm it is reluctant to part with its heat; it gives it up slowly and grudgingly, whereas rock disposes of it quickly. Thus water always has a moderating influence on the climate; it makes winters warmer and summers cooler. Land favours extremes of climate, continental summers are hotter and continental winters colder than average. So with the coming of land, the ball is set rolling; differential, not to say central, heating is installed, currents are set up in air and sea, evaporation is increased. Everything becomes magnified. We may be sure that if the Earth's surface were *all* land or even mainly land, it would alternately be so hot by day and so cold by night that life could not endure it. Something of the sort has happened on the moon, where there is no water, and no atmosphere either; any water there might have been has long ago been either vaporized and lost, or frozen solid.

If the ratio of land to sea, which is now about 1 : 3, were seriously altered, there would be a revolution in Earth climates. A mere change in the *distribution* of land and sea, without altering the present ratio, would be reflected in a change of continental climates all over the world. And as we know that the ratio has been altered in the past — 10 million square miles of land is submerged to-day which at some period must have been above sea-level, though not all of it at the same time — we may be quite certain that climates also have changed.

Movements of air and water are primarily responsible for climate. Air currents move far more rapidly than water currents. But the momentum of a vast bulk of sea water moving slowly and dissipating heat slowly has a long term effect which no air current can match.

There is another important factor, namely moisture. Air may be dry or moist. The atmosphere is able to absorb enormous quantities of invisible water vapour, and if there is a continuous current, continuously carry it away. When warmed, air expands and rises, still carrying the water vapour; and the

more it is heated the more vapour it can absorb and the higher it rises, expanding all the time But as it rises, it cools, and the more it cools the *less* vapour it can hold Consequently the higher it rises the more vapour it must get rid of — in the form of cloud Mountains, being colder than the plains, when they lie in the path of an air current containing moisture, always cause the formation of clouds If, on the other hand, the air is dry, it merely sucks what little moisture it can out of the land it passes over, leaving it drier than before

The influence of the sea may be easily observed in places like Singapore, close to the equator, where, owing to breezes set up between land and sea, due to differential cooling, the nights are always cool, as compared with breathless, hot nights when the sun is at the same altitude, in say Rangoon, 50 miles inland Speaking generally, in the tropics it is more comfortable to live on 'blue water' than even a short distance up a river Thus Hong Kong is preferable to Canton, and Swatow to Shanghai — for the European On the other hand, what the 'weather' feels like depends as much on the relative humidity of the air as on its temperature The damp cold of North Burma in winter is more trying than the far colder but drier air of Tibet, beyond the rain screen Different skins, and perhaps differently coloured skins, feel heat and damp differently.

In Assam the three mile wide Brahmaputra river, flowing across wide sandy plains which heat rapidly, develops winds which make the Assam Valley very turbulent for aircraft Thus big rivers, and especially lakes, have the same effect as the sea, and the conditions being rapidly developed in a continental area, may produce powerful, though local results

The climate of any particular locality therefore depends partly on its latitude, but still more on the nature of the atmospheric currents, that is to say, winds, which pass over it The nature of those currents in turn depends upon several factors, but by far the most important are the distribution of land and water, and the shape of the land (especially its altitude) in the locality

So far as life on the Earth is concerned, climate resolves itself

specific heat of any known substance The same sun warms the rocks quickly, the water more slowly On the other hand, once the water *is* warm it is reluctant to part with its heat, it gives it up slowly and grudgingly whereas rock disposes of it quickly Thus water always has a moderating influence on the climate, it makes winters warmer and summers cooler Land favours extremes of climate, continental summers are hotter and continental winters colder than average So with the coming of land, the ball is set rolling, differential, not to say central, heating is installed currents are set up in air and sea, evaporation is increased Everything becomes magnified We may be sure that if the Earth s surface were *all* land or even mainly land, it would alternately be so hot by day and so cold by night that life could not endure it Something of the sort has happened on the moon, where there is no water, and no atmosphere either, any water there might have been has long ago been either vaporized and lost, or frozen solid

If the ratio of land to sea, which is now about 1 3 were seriously altered, there would be a revolution in Earth climates A mere change in the *distribution* of land and sea, without altering the present ratio, would be reflected in a change of continental climates all over the world And as we know that the ratio has been altered in the past — 10 million square miles of land is submerged to-day which at some period must have been above sea level, though not all of it at the same time — we may be quite certain that climates also have changed

Movements of air and water are primarily responsible for climate Air currents move far more rapidly than water currents But the momentum of a vast bulk of sea water moving slowly and dissipating heat slowly has a long term effect which no air current can match

There is another important factor, namely moisture Air may be dry or moist The atmosphere is able to absorb enormous quantities of invisible water vapour, and if there is a continuous current, continuously carry it away When warmed, air expands and rises still carrying the water vapour, and the

more it is heated the more vapour it can absorb and the higher it rises, expanding all the time. But as it rises, it cools, and the more it cools the *less* vapour it can hold. Consequently the higher it rises the more vapour it must get rid of — in the form of cloud. Mountains, being colder than the plains, when they lie in the path of an air current containing moisture, always cause the formation of clouds. If, on the other hand, the air is dry, it merely sucks what little moisture it can out of the land it passes over, leaving it drier than before.

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into a question of temperatures and moisture, both rainfall and 'dampness' — *that is, rate of evaporation — and their distribution* throughout the year, depending to a lesser extent on the distribution of sunlight, which is essential to plant life For, as we have noted, life can only exist and persist under certain physical conditions, between certain temperatures, and in the presence of moisture Life on land depends upon the presence of water vapour in the atmosphere No geographer can afford to overlook the part played by climate, and still more by past changes of climate, in the distribution and migration of animals and plants, and not of animals and plants only, but also of man That climate has played a further part in influencing man's activities and opportunities is also undeniable, he may even owe something of his physical appearance and general disposition to the effects of climate, though if so, we are far from understanding what part climate plays Man is an adaptable animal and has long since adapted himself to a great variety of climates So also have other animals — and plants It would be rash to assert that a given climate produces a certain human type — for man may be a recent immigrant into that climate Or the climate may have altered since he came There is no obvious correspondence between even so apparently simple a factor as skin colour and climate, as exemplified in the distribution of races in the world to-day But we must not overlook the probability that the races of men were distinguishable tens of thousands, possibly as much as one or two hundred thousand years ago Their present distribution now gives no clue to their distribution then Only archaeological research can do that Moreover, world climates themselves were different then, and were also differently distributed, though they were not necessarily more extreme than they are to-day Temperatures lower than those experienced in Siberia, or higher than those of North West India, have probably never been known in the inhabited parts of the world But long before man appeared the Earth was enjoying slow changes of climate

Some of our cherished beliefs as regards climate and man are

certainly wrong For example, a tropical climate is generally regarded as enervating, and productive of laziness, and there is at least enough evidence in the modern world to lend colour to the idea Yet exceptions — if the general rule holds good — are too startling to be ignored For example, the southern Chinese of the Canton delta who live in the tropical zone are far more mentally alert, physically active and morally dynamic than the stolid northern Chinese of say Peiping Again, we see the so-called lazy Burmese inhabiting a tropical land, and straightway conclude that they are lazy just because they live in a hot country whence an abundant food supply is easily obtained without undue trouble It is questionable whether the Burmese deserve to be called lazy Assuming, however, that they do, nobody seems to have considered that possibly they migrated into a hot country where food is easily raised, *because* they were lazy It might be as difficult to prove the one as the other The Tibetans who inhabit a cold climate are not noticeably energetic, and the cynical might call the Tibetan monks downright lazy

In so far as climate has helped to make man what he is, its influence appears to be small It may be that great and con stant humidity has in course of time a debilitating effect, but there is no good evidence to show that great heat cannot be borne even by the white races, without deterioration

While certain plateau climates in the tropical and sub tropical belt appear to be amongst the best all round climates in the world, no realist would suggest that the Mexicans, for instance, or the East African negroes, or the Shans were amongst the most energetic, progressive or enlightened races on Earth

As regards skin colour, F P Armytage has suggested that pigmentation is a function of the available salt supply Salt, in the form of saline solution, activates the blood stream, its absence causes a thickening, with consequent slowing down of the blood stream and deposit of pigment, as a river deposits silt Armytage showed clearly that the darkest skinned races

were those which had the greatest difficulty in obtaining salt. If the availability of salt is bound up with the climate — and sometimes it does seem to be — we may here find a clue to the puzzle. It is certain, for example, that salt is difficult to obtain throughout the very wet and mountainous country, mostly covered with dense jungle, between Sikkim and Western China. The number and variety of blood-sucking creatures found here — leeches, mosquitoes, ticks, sand-flies, blister-flies, horse-flies, gad-flies and others, and the manner in which insects of all kinds, including bees, butterflies and numerous Diptera, plague humans in the jungle, to suck their sweat, is a further indication of this. Salt licks are rare — the exceptionally heavy rainfall throughout this region and the high jungle may have something to do with this lack of salt, which is easily washed out of the soil. But the tribes who sparsely inhabit this forbidding region, though dark-skinned for a Mongoloid people, are far from black.

What does seem abundantly clear is that climate alone has no direct action on skin pigmentation.

There is no necessity to probe more deeply into the difficult problems of climate. That is the meteorologist's or climatologist's job. All I wish to do here is to draw attention to climate as an important geographical factor. It has deeply affected man's way of life, his food and work, his architecture, the animals and plants he has domesticated, and so in ever widening circles, his environment, outlook and background.

That some climates are reckoned better than others is indisputable. But — better for what? People grow accustomed to their home climate and, never having known any other, are *satisfied* with it, however unpleasant it may seem to a stranger. But history shows that on the whole men covet certain parts of the earth more than others, and have striven amongst themselves again and again for mastery of plains, deltas and wide fertile vales, in the temperate zone. Not perhaps for the sake of the climate itself, but for certain consequences of that climate.

Thus the extraordinary variety and range of climate met with all over the world to-day are due to two causes: (i) the breaking through of the underlying crust into the atmosphere to form land and (ii) the elevation of that land into mountains of greater or less height, coupled with the different physical properties of rock and water, whereby they heat and cool at different rates.

While the influence of climate on mobile man is obscure, its influence on static vegetation is comparatively obvious. We may therefore next consider a few contrasted examples.

TROPICAL JUNGLE

ANYONE who has ever travelled, even if their travels have taken them no further than from London to the Riviera or to the Highlands of Scotland, must have been struck by the different appearance of the vegetation in different places, not merely individual plants but the total wild vegetation. A great deal of knowledge has been accumulated concerning the vegetation in all parts of the world. I propose to confine my remarks to two extreme types of land cover: namely, tropical evergreen rain forest and alpine. This will give some idea of the effect vegetation has on the Earth. I shall then go on to consider naked land or desert.

The greater part of the land surface of the Earth is more or less concealed beneath a mantle of vegetation — or was until fairly recently, when man started ripping it up wholesale wherever he could get at it. Even so, about 1/7th of the total land surface is desert or near-desert and so covered with a very threadbare mantle, or with no mantle at all.

Plant life, like animal life, no doubt originated in the sea. The primeval crust, the first land to be raised above the surface of the hydrosphere, had of course no vegetation. Volcanic islands sometimes appear suddenly in mid-ocean, and they also have no vegetation. Occasionally all the vegetation on an island is destroyed by a volcanic explosion, as may perhaps have happened on Krakatoa, when it was blown up in 1883, though this is not an established fact. Such islands are then deserts, but they do not remain deserts. After a time a film of vegetation, consisting first perhaps of flowerless plants and later of flowering plants, begins to spread over them. The spores of the former may be brought by air currents, the seeds of the latter by ocean currents and by birds. Or sea-borne

fruits, like coconuts, may arrive first. If the climate is warm and humid, and frost unknown, and if rain is plentiful and well distributed throughout the year, it is only a question of time before the island is covered with one of the highest possible types of vegetation, that is to say with tropical evergreen rain forest. It may take a thousand years to develop, but that is nothing. Volcanic soil is rich in mineral salts, needing only humus which is derived from vegetable matter through the agency of bacteria, and this will gradually accumulate — provided the bacteria are present.

The quality and quantity of vegetation in any region is dependent mainly on climate. Given sunlight, of the several climatic factors humidity of atmosphere and adequate water in the soil are the most important, and of these two, atmospheric humidity has the greater influence on the vegetation. For if the air is constantly dry, no amount of water in the soil will be of much use — apart from the fact that the water may be salt. An oasis in the desert is, of course, compared with the desert, a Garden of Eden. Nevertheless, it is a very scraggy garden compared with more favoured lands. If rain falls frequently, the air cannot be dry.

Intermediate between near desert and forest are the regions known as steppe, prairie, pampas, savanna, llanos, campos or meadow. The temperate grassland areas such as meadow, steppe, prairie may be regarded as intermediate between tundra and temperate forest, savanna (or in South America llanos) as intermediate between hot desert and tropical evergreen forest.

But though water controls the type of vegetation in general, it is not the *only* factor which influences it, it is only the most important factor. Temperature also is important, and so important that if the temperature is constantly below a certain minimum, all the water in the world won't bring vegetation, for the water will be ice.

As an example in transition from one type of vegetation mantle to another, suppose we make a journey eastwards down

the Tsangpo valley, from the neighbourhood of Lhasa, altitude 12,500 feet, to the great gorge where the Tsangpo breaks through the Himalayas. The outer plateau of Tibet, though treeless and arid, is by no means a desert. Along water-courses and in villages where irrigation is practised, there are even a few stunted trees, willow and elm. Large areas, however, are devoid of any visible plants forming patches of sandy or stony desert, especially in the river valley itself where sand dunes are a feature. The hillsides are covered with scattered thorny undershrubs and small herbaceous plants, in limited variety, most of these disappear in winter, though continuing to exist underground. The country, in fact, looks extremely barren. The first trees to appear are junipers, not forming forest, but growing scattered along the river bank, meanwhile shrubs and herbs have been steadily increasing in number, variety and size. Now conifer forest appears, not down in the valley, but 1000 or 2000 feet above the river, where it gets more rain and less wind. Gradually the forest descends until at last just before the river enters the gorge the valley itself is filled with conifer or even with mixed forest.

Next comes mixed forest, about 50 per cent of the trees being species of rhododendron, with various conifers, but gradually deciduous broad leafed trees increase and replace the rhododendrons. By the time we have reached 6000 feet altitude, we are in typical Himalayan temperate forest where birch, oak, maple, chestnut, and magnolia are the commonest trees.

From a consideration of the above transition we may conclude that the change from cold near-desert to temperate forest is at least partly governed by temperature, and is thus a matter of altitude or of latitude. But it is even more governed by humidity and here wind plays an important part. The absence of trees on the outer plateau of Tibet is in reality due more to wind, and thus to drought, than to low temperature.

Similarly the difference between hot desert and luxuriant jungle is mainly due to a difference of moisture content in both air and soil. Desert and rain forest are extremes, connected

by several intermediate but not necessarily successive stages The alpine region passes directly into cold desert as altitude increases

Formerly evergreen rain forest must have covered most of the land surface within the equatorial belt, say for 10 degrees on either side of the equator It still covers large areas in the Congo basin and in Portuguese East Africa, in the Amazon basin, in Guiana and Venezuela, and in New Guinea and other islands between Queensland and Malaya This type of forest extends beyond the equatorial belt, and even outside the tropics altogether if conditions are peculiarly favourable, as in the foothills of Upper Assam and North Burma

But the total area of land surface within the tropics is only about 19 million square miles, of which not more than half is to day forested If, however, we add to this all the forest area in the world, including monsoon (deciduous) forest, temperate forest, conifer forest and so on, we find that there is still a fair amount of forest left, though it is dwindling every year

What then are the characteristics of tropical evergreen rain forest? Let us look at the vegetation of the world through the eyes of the botanist geographer

Although tropical evergreen forest is the most varied and luxuriant type of forest in existence it does not contain the largest trees Nor is it the most impenetrable type of forest The tallest trees, the Redwoods of California and the Blue Gums of Australia, both occur outside the tropics As for impenetrability, the hill jungles of Burma and Assam, the moss forest found at considerable heights in Malaysia, even the rhododendron forest of cool elevations in the Eastern Himalaya are equally impenetrable, and probably more so Here, however, the slope of the ground increases the difficulties For quite other reasons, mangrove swamp forest may be impenetrable There are also extensive forests in regions well outside the tropics, where the winters are cold, which have far fewer species and less variety than wet tropical forest, where it is almost impossible for a man to get through, perhaps the most

impenetrable forest in the world is found in the Great Kinghan mountains of Manchuria

In fact impenetrability is not an outstanding characteristic of tropical evergreen forest, though it may often be necessary to cut one's way through The botanical characteristics of tropical evergreen forest are, firstly, the great variety of tall trees with wide-spreading umbrella like crowns, forming a nearly closed canopy overhead, secondly, the abundance of long slim woody climbing plants, ribbon or corkscrew shaped, which help to fill up gaps between the crowns of the trees, and take up much of the space between the trunks, often lying in coils on the ground, thirdly, the wealth of epiphytes of all kinds, that is of plants growing on other plants, usually on trees — on their trunks and branches, and even on their leaves, as a result of this inside the forest the light is dim, the humidity from lack of sunshine and wind, high Consequently there is often comparatively little undergrowth Creepers, prickly climbing palms, and plank buttresses supporting the trees — that is upright triangular plank like outgrowths of the roots radiating from the bases of the trunks — sometimes make this type of forest difficult to get through, not to mention swamps, fallen tree trunks and rocks

The above details are, however, hardly the business of the geographer, except in their wider implications

What *is* important to the geographer is the fact that fire cannot enter wet tropical forest, unless it is first felled and dried out This has been a great protection in the past, and even to-day slows down its destruction Nevertheless, evergreen forest is being steadily and ruthlessly destroyed in certain parts of the world notably in South East Asia, and since it occurs only in regions of heavy rainfall, and usually in hilly if not hu untainous districts, the results are the more striking Apart of tre the actual loss of timber, of economic plants generally, wind, a are trees — this last not a serious consideration in a Simula uled by the doctrine of quick profits — the run off is jungle is ncreased, rivers are choked with sediment leading to ir and so

floods lower down, and soil stripped away, not perhaps to be replaced in a thousand years For the vegetation mantle of the Earth is a protective armour It protects the crust from the consequences of its contact with the atmosphere Once the armour is pierced, hillsides may be unable to support any vegetation, and are at least unfitted to support forest They may, as in parts of Malaya, still support a rank cover of grass, but equally every vestige of soil may be removed, leaving nothing but bare rock Enormous slabs of naked rock have been exposed by this means in North Burma in the valley of the eastern Irrawaddy These bare rock faces heat the air locally, causing it to rise, thereby lowering the rainfall in the valley and gradually altering the local climate

Forest has to be cut down and cleared by the inhabitants of the hills in order that they may grow crops Under present conditions shifting cultivation is carried on — new clearings are made each year But unless this can be brought under control and the destruction of wet forest carried out according to plan, particularly in the hills, very serious troubles are in store sooner or later The question of forest conservation within the catchment area of a river falls within the province of a body such as the T V.A of America

Wet tropical forest occurs only under certain climatic conditions — high and constant humidity with frequent and usually violent showers to maintain it, plenty of bright sunshine, a temperature which never falls much below 70° F, or rises much above 90° F, and a more or less equable distribution of light and darkness throughout the year Consequently there are no seasons and apart from day and night almost no change throughout the year Constant and static conditions are the rule

The prevalence of such conditions depends mainly upon two factors (i) latitude, (ii) the distribution of land and sea But there is also another factor which is important, namely, the elevation of the land and the distribution of high land Even in the equatorial zone, the best conditions are more likely to

obtain in the hills than in the plains. If the equatorial belt consisted mostly of land or of broad masses of land separated only by narrow belts of water, instead of as now, 1/4th land and 3/4ths water (almost exactly the same proportion as over the entire Earth), there might be more desert than wet tropical forest here. As it is, where the equator crosses wide land masses, wet tropical forest is confined more or less to the narrower northern part of South America within the Amazon basin, Guiana and the Orinoco valleys, and to the narrower waist of Africa, from the Gulf of Guinea (Cameroons and Congo basin) to the Mozambique Channel. On the other hand the east end of Java is noticeably drier than the west end, and the coasts of the former Italian Somaliland, of northern Australia west of Darwin, eastern Ceylon, the western end of Timor, Annam, and Peru are arid. This is hardly in accordance with expectations and indicates the almost whimsical manner in which rain-bearing currents not merely by-pass, but even flow harmlessly over regions where one might reasonably expect continuous heavy rainfall; so that the distribution of wet tropical forest is also occasionally unexpected.

In many parts of New Guinea, not a week ever goes by without rain, such localities being generally in or close to the hills. This is true also of the foothills of Ruwenzori and perhaps of the Cameroons.

The two chief climatic conditions necessary to maintain wet tropical forest are humidity and temperature, but especially humidity. As this drops, a change takes place not only in the type of vegetation, but also in its composition. Evergreen forest is replaced by monsoon deciduous forest.

But so long as humidity is maintained at a high level dense evergreen forest is the rule, even in a temperate climate. We have just noted that a dry season is far more potent in upsetting the rain forest than is a cold season. As one recedes from the equator, seasons become more distinct, temperatures less equable, the distribution of light and darkness more seasonal. Yet many of the characteristics of wet tropical forest persist

well beyond the tropics, because the humidity remains constantly high Assam, for example, is shaped like a funnel with its open mouth to the south-west and converging ranges of mountains on either side As a result the monsoon winds blow up it with increasing force and the foothills are ever moist, and covered with wet tropical forest as far north as lat 29 degrees, in spite of increasing altitude Humidity on the whole increases with altitude, and so also does the luxuriance of the forest, until a point is reached where increasing cold outweighs the advantage of increasing humidity, and the forest becomes more open at higher altitudes the trees are smaller, of fewer and of course of different species, in different proportion There may be fewer climbers (though more epiphytes, which depend chiefly on a humid atmosphere, whereas woody climbers demand a high temperature), and the canopy may be less complete Nevertheless, owing to the form of the trees, to the increased undergrowth, to the development of mosses and bamboos and increased numbers of shrubs, the forest is still thick

Conditions in North Burma are much as in Assam, and dense, impenetrable forest is found in places as remote from the equator as Tierra del Fuego, the west coast of Chili, Tasmania, Manchuria, and Vancouver Island As to altitude, at 7000 or 8000 feet in Java or New Guinea or half way up Ruwenzori the forest is impenetrable

The bearing of all this on human progress in certain parts of the world is significant Early man, who got himself mixed up in this type of forest, was trapped He could make no headway He possessed neither the tools for making clearings nor the knowledge for raising crops All the advantages which the tropics conferred on him by reason of their wealth of vegetation and easy climate were wasted He could be a hunter and nothing more It was not until very much later, when man *was* already civilized, that he learnt to subdue the tropical vegetation One has only to compare the culture of the North American Indians with that of the tribes inhabiting the Amazon basin to see what this implies In Africa, the tribes

north of the Sahara were far more advanced than those in the equatorial belt So also were those south of 20 degrees Not the climate, but the vegetation resulting from climate is responsible for these differences On the open plains or along the coast, on the fringes of the desert, and even in the mountains if cold enough, man could at least get about, and *see* about, exchange ideas, compare his experiences, correct first impressions But the jungle was a prison, and in tropical mountains where the jungle is most impenetrable, it was more so than on the plains So tribes became isolated in watertight compartments — valley separated from valley by mountains covered with tropical evergreen jungle, such as is found throughout South East Asia

A region of great geographical significance is the belt of tropical and sub tropical evergreen forest which separates the agricultural regions of China from those of India The mountains themselves play an important part here Yet it is certain that had they not been covered with impenetrable forest, migrations and armies trampling to and fro between China and India would have altered the destinies of the East A southward extension of this forest belt kept the bulk of the Tai Chinese and Tibeto-Burman races apart

For the jungle conquered primitive man Centuries were to pass before man conquered the jungle — if he *has* yet conquered it

As tropical evergreen rain forest — to give it its full title — is the highest type of plant community, so when it is destroyed it is the most difficult for Nature, in spite of all her patience and ingenuity, to restore How long it takes to come back, how prolonged each successive step in the gradual process of reconstruction may be, are questions which cannot be answered But since many of the trees in mature rain forest are themselves likely to be at least two or three centuries old, it can hardly be less than five hundred years, and may quite well be a thousand years old That is always supposing that Nature *can* restore it

VII

ALPINE REGIONS

As a contrast to tropical jungle let us now consider alpine regions, which stand at the other end of the scale Evergreen rain forest owes its presence to a certain combination of heat and moisture such that the chemical processes of growth are continuous throughout the year In the alpine region and in the Arctic, plant growth reaches its highest possible degree of intermission

The word Alps has become current for almost any mountain region high enough above the timber line to include turf, or tufted grass-covered hills and valleys, more accurately denoted the alpine zone Thus while no one has yet been bold enough to speak of the Himalayan Alps, we have on good authority the Alps of Chinese Tibet, New Zealand Alps, Japanese Alps and the Alps of Burma

To botanists and geographers at least the alpine zone is a definite region where certain conditions prevail It does not denote a particular altitude, for alpine conditions may occur at almost any altitude between sea level and 13,000 feet, not altitude, but climate controls the alpine zone All mountain ranges which rise above the tree line have an alpine zone, which extends between the timber line and the snow line. In New Guinea the timber line is at 11,000 feet, the snow line about 15,000 feet In North Burma, Eastern Assam, and on the southern face of the Himalaya, the timber line stands at about 12,000 feet Above that altitude the climate is too harsh for trees In some parts of Eastern Tibet, however, trees grow at 13,000 feet Somewhat similar conditions are met with as one travels northwards in the northern hemisphere, or southwards in the southern hemisphere, at progressively lower altitudes In the European Alps (lat 47 degrees) the tree line is at about

6000 feet, in Scotland, 10 degrees further north, at about 2500 feet There are no trees on the Siberian tundra, a few hundred feet above sea-level, or in Canada north of 60 degrees. In other words the alpine zone, now more correctly called Arctic, has here come down to sea-level. But though climatic conditions in the Arctic bear a certain resemblance to conditions at 12,000 feet in the Himalaya, sufficiently so to make it difficult to say whether a given plant, for example, comes from one or the other, they are by no means identical The Arctic flora does indeed bear a certain outward resemblance to the alpine Himalayan flora — there are even species common to both regions Comparable climatic conditions have hall-marked the vegetation of both regions Nevertheless, the one is an Arctic flora, the other an alpine flora, and it is a mistake to confuse them. We should find much less resemblance between the alpine flora of New Guinea, for example, and that of the Arctic. On the other hand it must be confessed that the alpine flora of New Guinea bears little resemblance to the alpine flora of the Himalaya.

Thus it would be absurd to compare the Arctic plains of Siberia or of Canada with the Himalaya mountains, in spite of a certain resemblance in their floras Alpine plants grow above the tree line in latitudes where trees grow. If there are no trees, as beyond the Arctic circle, the flora is an Arctic one.

Here alps means mountains, and not only mountains but snow mountains; the alpine zone means the treeless zone which stretches from the tree line, wherever that may be, to the line of permanent snow.

Just as when we travel northwards climate becomes more extreme, notably as regards fall of temperature, so when we climb a mountain, even if it is on the equator, the cold becomes more severe As a result, the type of vegetation changes, different species and a different life form better adapted to the changed conditions replacing it. But before a major change takes place the vegetation becomes more stereotyped, owing to many less tolerant species dropping out. Gregarious species

become dominant Plants huddle together as though for warmth

In temperate mountainous regions, before the tree line is reached, conifer forest becomes dominant, replacing broad-leafed forest sometimes with one, sometimes with several conifers But as soon as the climatic conditions become so tough that not even these trees can survive, that is to say, directly the tree line is passed and another type of vegetation appears, a wealth of new species breaks out This alpine vegetation, herbaceous and shrubby, is far better in tune with alpine conditions than are trees Hence the exuberant plant population bursts out into a wide variety, as well as occurring in countless numbers, and the result is startling In the North Burma Alps there is a continuous but gradual transition in the vegetation as one ascends from sub tropical rain forest in the deep valleys, through temperate forest and conifer forest, to Alpine Between 1000 and 6000 feet altitude the number of species of trees steadily decreases Between 6000 and 10,000 feet altitude it decreases faster But the moment the breaking point for forest is reached, and an alpine flora replaces a forest flora, a vigorous reorientation of plant life occurs There are probably as many species of alpine plants above the timber line as there are of trees and shrubs in the sub tropical belt Two abrupt changes in the total number of species may be noted as the vegetation changes with altitude, the first at about 9000 feet altitude with the change from broad leafed to conifer forest, marked by a decrease in the number of species, the second at 12,000 feet, marked by a sudden increase

Alpine regions occur in all the great mountain regions of the world, in the Andes the Rockies, in New Guinea, on the mountains of equatorial Africa, in the Tian Shan, in Manchuria and the Carpathians and alpine regions everywhere have something in common, which is indicated by the type of vegetation known as alpine The geographer will note with interest, however, that where snow mountains occur near the equator, or perhaps anywhere inside the tropics the alpine zone

deep, clogging the main torrents which presently tunnel beneath them These snow beds persist for months

The question I think does arise — will more use or new use be made of alpine regions in the years following the war, and if new use, *what* new use? We may dismiss the alpine regions of equatorial mountains as unsuitable for any purpose we can at present conceive These small areas are a mere curiosity of nature, and are likely to be preserved — as national parks — without any effort on our part

But the great alpine regions of the world are not in the equatorial belt, or even in the tropics They are in the mountain ranges of sub tropical and temperate regions in North and South America, in Europe and above all in Asia Even North Burma and Eastern India, where the vegetation in the valleys is still sub-tropical in its luxuriance and the precipitation on the heights, both as summer rain and as winter snow, is excessive, have a genuine alpine belt, fit for summer residence and grazing

In Eastern Tibet and Western China or Sino Himalaya the greatest areas of alpine country are found Here behind the rain screen which shelters them from the worst of the monsoon summer rain are vast areas of habitable country, fit for grazing, and, if the right crops and fruit trees were introduced, for agriculture The difficulties which agriculture has to face here are less than those which farmers in Manitoba and Saskatchewan have faced — as far at least as climate is concerned, for there is a growing season of more than 100 days — and in fact we know that crops are grown at over 13,000 feet in Tibet and at over 6000 feet in North Burma It is only accessibility to markets which is lacking But that is no reason why the inhabitants of these regions, who are extremely poor, should not be encouraged to raise their own standard of living and share in some of the good things of the Earth Fruit and vegetables, milk and meat, besides crops, could be grown in the alpine regions of Asia where the pastures are rich, the soil fertile and the air bracing It should be a land of bright

gardens. Drought at least is unknown; and the absence of mineral wealth will keep the clash of rival economic interests at bay for some time to come.

Above 14,000 feet it is chiefly lack of soil which restricts vegetation. There is plenty of vegetation in favourable spots. The Alps, especially in regions of heavy precipitation and extremes of temperature such as North Burma, are dynamic, the scenery violent. Many hundreds of square miles of high mountains are uninhabitable, though useful to food-and-medicine-gathering people.

By August or September most of the snow beds below 12,000 feet have disappeared, but above that altitude many of them never melt. They influence the local weather considerably, keeping the valley in cold storage. Examination of a snow bed late in the summer reveals that the surface is concealed beneath perhaps half an inch of vegetable matter and dust, which can only have been blown on to the snow by wind. As the snow melts this layer is deposited over the soil, thereby enriching it.

These snow beds are the cause of some curious happenings in the lower valleys, not the least curious of which is the burying of spring-flowering alpine plants. Such plants are often not released till the autumn; nevertheless, as soon as they *are* released, they start to grow rapidly and, though dwarfed, may flower before winter cuts them down. Thus one can see on the flanks of a valley, where a snow bed is melting, species of primula, iris, and other plants in ripe seed on the south side, whence the snow has long since melted, and the same species just coming into flower close to the snow on the north side, within a hundred yards!

Nowhere are the effects of weathering so obvious as in the alps, which are regions of furious demolition and reduced transport. On the plains, rivers charged with mud testify to the fact that the material of the crust is being carried away to sea, and inspection of any delta will show land in process of formation. Smoothed, flat and rounded features result. In forested mountain regions one can hear the rocks in the torrent rattling

and banging against one another and watch stony banks being undermined and carried away. Here demolition and transport perhaps balance one another, and vegetation has a conserving effect But above the timber line transport lags far behind and demolition is continuous and violent Consequently material rapidly accumulates and valleys tend to be filled in All day long throughout the summer rocks are falling, only to cease in winter When the thaw comes the destruction reaches its maximum and so too, for a short time, does transportation but it never catches up and accumulation goes on The rocky sky-line changes every year

In the very moist mountains of the North-East Frontier of India these features are emphasized Everywhere the surface is covered with loose rock, the largest rocks rolling to the bottom of the alpine valley where accordingly no soil can accumulate Much of the drainage lies deep beneath a layer of boulders Further, there is a marked tendency for north facing slopes where the snow melts more gradually to be protected by a carpet of vegetation, while south and west slopes are unprotected and exposed to the full fury of the elements

Just as the hill tribes of Burma and Assam cut and burn the jungle in order to make way for their crops, so the herdsmen in the Eastern Himalaya cut and burn the rhododendron scrub in order to increase the pasture The effect is startling Instead of promoting the growth of grasses, sedges and other pasture plants it encourages the growth of one or two favoured rock plants, notably a species of primula (*P Dickieana*) which occurs in astronomical numbers near the tree line where clearings have been made by burning the rhododendron scrub This is partly due to increased marshiness Now yak will not touch this plant, so that the only result is to cover the alps with it, and not only so, but to spread it still further Another plant which comes up freely in places where rhododendron has been burnt is *Meconopsis grandis* Thus it would seem that in some parts the alpine pastures are being ruined by the spread of what nurserymen would call 'new and rare alpines'!

an unrivalled field for discovery and research. Mountaineers will find scores of unclimbed peaks on which to try their skill. They are regions not primarily of food production, nor of residence, nor of commerce and industry, but regions where knowledge lies sleeping, awaiting the magic touch which shall waken it to life. And it may well be that from the grandeur of their form and the challenge of their solitude, no less than from the harshness of their climate and the vigour of their sublime colouring, these infinite mountains are also the realm of spiritual peace.

What part will the alpine regions of Asia and America play in the new world? Though generally uninhabited, they have nothing else in common with deserts, much in common with Arctic regions. Where, as in the Burmese Alps, snowfall is very heavy, they are uninhabitable in winter, their passes blocked. But in summer they are temporarily inhabited by people from the villages in the valleys bringing their herds to graze. North Burma, however, could support a far greater number of cattle in summer. The chief difficulty is how to keep them healthy during the winter, when they must live in the forest belt below 9000 feet. Salt too is lacking and more would have to be imported. In South-Central Tibet, Western China and other parts where the snowfall is less heavy and winter humidity lower, there are villages and monasteries as high as 13,000 or even 14,000 feet. Similarly in the Andes, where the whole inhabited region is alpine. Glaciers occur on these drier plateaux in place of snow beds.

The alpine regions then are grazing lands (though crops are raised at 13,000 feet in Tibet) and, economically, nothing more. In Tibet, great numbers of *dzo*, sheep, goats and ponies graze. They yield rich milk and butter, wool and hair, also skins, and these products are worth improving. It is likely that, as in other parts of the world, large areas are being rendered unproductive through ignorance. At present the contribution of Tibet to its own inhabitants and to world markets is negligible. But some day it might be an important source of supply, in exchange for some of the things which Tibet lacks: for example, huge quantities of butter are consumed in the ceremonial lamps of the monasteries. Kerosene would be better.

However that may be, the whole of the mountainous region from Kashmir to Cathay is distinguished by an unparalleled wealth of beautiful flowers, many of them able to grow on the plains further north, thus emphasizing that affinity between high altitude and high latitude already referred to. Not a few are endemic. Explorers expert in any branch of natural science, botany, zoology or geology, will find in these remote alps

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VIII

DESERTS

DESERT is the name given somewhat loosely to those parts of the land surface which support little or no life, animal or vegetable. The quantity and perhaps also the variety of animal life in any region is more or less proportional to the amount and variety of the vegetation, since it is vegetation which directly or indirectly provides food for all animal life. With the dwindling of forest and pasture animal life too dwindles, to disappear completely in the desert; complete absence of vegetation implies complete absence of animal life also, at least of resident animal life, though few large areas in the world are *completely* devoid of vegetation.

In desert or near-desert regions then there is little or no animal life because there is little or no vegetation; there is little or no vegetation because there is little or no water; there is little or no water because there is little or no precipitation, that is to say, rainfall or even dew, or because the precipitation is in the form of snow which never melts. The reason for scanty and irregular precipitation must be sought in the circulation of the atmosphere which carries the water vapour of rain and dew, and in the land shapes which cause vertical air currents—ultimately in the distribution of land and water and the height of the land.

The only other possible source of water in desert regions or anywhere else is underground, so-called meteoric water, which, coming to the surface as a spring, forms an oasis. This water too originally fell as rain, or as snow which melted, and percolated slowly underground to its present position at the bottom of a 'basin'; to reappear above ground at a height not greater than the level at which it stands in the basin.

It is important to realize that desert conditions are the result

of prolonged drought (that is the absence of water) because evaporation exceeds precipitation But exactly the same result is attained, so far as life is concerned, if for any reason vegetation is unable to absorb water even when it is present

This frequently happens either because the soil is frozen or at least nearly frozen, and its water content solid, as in Siberia and Northern Canada, or because of the presence of an excess of salt in the soil as in many parts of Tibet, in the Australian desert, in the Great Salt Lake basin of the South Western United States and elsewhere, and perhaps for other reasons Snow, of course, cannot be taken up by the roots of plants until it melts, and plants cannot as a rule drink salt water any more easily than animals can Most land plants grown in a salt marsh would suffer from thirst exactly as a man at sea in an open boat suffers from thirst, and like him would soon perish for lack of water Tundra is the name given to the Arctic plains of Siberia where it is too cold and swampy for trees to grow *Tundra is cold semi-desert*

Thus it is convenient to distinguish between the hot low lying deserts of the tropical and sub tropical belt, and cold deserts in high latitudes or at high altitudes In the former, which are on the whole areas of high pressure, evaporation exceeds precipitation, so that there is a more or less perennial shortage of water, with consequent absence of vegetation In the latter there may be plenty of water, as in the swamps and deltas of the tundra, but the soil is too cold for the roots to function, or else the water is frozen solid, or it is salt

Thus the tundra, the high plateau of Tibet and other places where *physiological* drought prevails are just as much desert as Libya and Arabia There is plenty of water, but so far as vegetation is concerned it is as a mirage in the hot desert A few specially equipped plants can survive where the water is salt if the soil is not frozen

One might suppose that since water vapour is drawn up from the sea by the heat of the sun (and the hotter the sun presumably the greater the evaporation) deserts, wherever else

they might be found, would be absent along the seaboard and particularly along a tropical seaboard Manifestly that is not true It is indeed surprising how many thousands of miles of arid, barren coast do in fact fringe the seas of the world, and especially the warm seas There is no obvious relationship between rainfall and distance from the sea The coast of North Africa, familiar to many people nowadays, is fringed by deserts for 2000 miles, and conditions rapidly become even more severe inland, especially behind mountain ranges like the Atlas Arabia is no better off, as those who have visited Aden must have noticed Round a large part of Australia again, the desert comes down to the sea, as it does in Northern Chile Even the coast of Annam on the South China Sea is arid and near desert inland as far as the Annamite Chain 'The existence of small arid islands in the Indian Ocean, the barren shores of South Morocco and the desert on the coast of South Peru show that the mere proximity of even an ocean does not ensure a moist climate '[1]

Having been taught in our youth to associate deserts with intense heat and intense heat with the tropics — few of us I suppose easily learn that Delhi is in almost the same latitude as Shanghai and Shanghai in the same latitude as New Orleans — we come to believe that the greatest deserts must be close to the equator At least we are tempted to believe it, and no doubt would do so, did we not also recollect that the hotter the sun the greater the evaporation, and the greater the evaporation (perhaps) the heavier and longer the rainfall This line of thought lands us with an apparent contradiction, even a paradox, hard to resolve

We have just disposed of the fallacy that there are no deserts near the sea, for though the evaporation over the sea is great if the wind blows outwards from the land the water vapour cannot reach the land As we realize now, there are thousands of miles of desert coast both within and without the tropics, it is not the proximity of the sea but the direction of the air currents that controls the formation of clouds and determines their destina

[1] *The Dead Heart of Australia* J W Gregory

tion. The fact is, what many of us were taught in our youth about deserts and heat was not the whole truth and nothing but the truth. Rather was it anything but the truth, or at best a half truth. The equatorial region is not the hottest place in the world — though it might be, were land and sea differently arranged. And as to the alleged intense heat of deserts, most of us realize nowadays that though intense heat is rightly associated with 'hot' desert regions, temperature is only one of several factors favourable to the birth of desert conditions. Actually intense heat, due to radiation, is as much a result as a cause of deserts.

However we are right in associating intense heat with the Libyan or the Arabian desert by day, during the summer, so long as we understand why we must associate intense or at least severe cold with those places by night during the winter. The tropical and sub-tropical desert is essentially a region of extremes. In Libya for example the shade temperature ranges from a minimum of 40° F. in winter to a maximum of 120° F. in summer. It owes its desert nature however not to high temperature but to low humidity, not to heat but to drought, which is a very different thing; for drought, though assisted by heat, can be caused by quite other agencies. It is by no means certain that if the mean temperature of Libya were suddenly lowered by 10 degrees there would be any lessening of the drought — any increase of precipitation, even after the lapse of years.

Nor must we expect the Siberian tundra or Central Tibet ever to be hot or even pleasantly warm; they are both frigid deserts.

Deserts originate in various ways, but most of the deserts in the northern hemisphere are post-glacial — that is they date within the last 10,000 or 15,000 years. There appears to be no evidence of serious changes of climate in Asia, resulting in the formation of great desert tracts, within the historic period; and few geographers nowadays believe that pulsations of climate in Central Asia, so skilfully expounded by Huntingdon, were the

main cause of the periodic irruption of the nomads into surrounding areas

Nevertheless, the heavy hand of man has converted millions of acres of once fertile country into sterile barren wastes by neglect, by greed, by impatience for quick returns, by ignorance and by sheer thoughtlessness As though to make amends for his ill-treatment of the land, involving the destruction of soil fertility over vast tracts, twentieth century man is actively engaged in irrigating deserts in many parts of the world Since desert soil is often extremely fertile — for example in the loess regions of North Western China, and all that is needed to bring back vegetation is water, a well devised irrigation plan will make such deserts blossom

Sometimes as in South Australia and Queensland deep seated water is present, and it is only necessary to bore wells to reach it But since this is apparently plutonic and not meteoric water, these flowing wells are not inexhaustible (Gregory)

More often, to irrigate deserts or arid country such as Central India, it is necessary to bring stored water from a distance Primitive irrigation by means of long distance aqueducts is carried out on a small scale in Eastern Tibet

Irrigation of course is no new idea, although modern technique with its dams, reservoirs, pumping stations, pipelines and so forth is very different from the happy go-lucky technique devised by simple peasant communities several thousand years ago But not different in principle The Babylonian canals in what is now Iraq drew water from the Tigris 4000 years ago and distributed it over hundreds of square miles of desert

The 25 foot bamboo water wheels of Szechwan in Western China, made to revolve by the current and so lift water from the river in bamboo tubes to pour it on to the fields as they turn, and the wooden flumes of Tibet drawing off the water of a mountain torrent are examples of simple irrigation devices

But to irrigate deserts on a large scale something more is needed, especially in a hot climate The modern irrigation engineer is a highly trained specialist. When we recollect

that nearly 3/4ths of the lithosphere is under the sea, and when further we recollect that the hydrosphere as a whole, including land based water, has a moderating effect on the climate, we may well be astonished at the area of desert and near desert in the world The total land area is nearly 56 million square miles Of this, something like 20 million square miles, roughly 2/5ths is desert or near desert No wonder the 2000 million people in the world over wide areas appear to be thinly spread, while elsewhere they appear to be congested Much of the surface of the lithosphere under the sea is also virtually desert, supporting neither animal nor plant life Here however we are considering only the visible surface of the globe, where what we have described as the film of life finds sustenance so long as water is present in sufficient quantity and in potable form. If land and water while retaining the same relative ratio of nearly 1 3 were more evenly distributed the ratio of desert to well watered land might be decreased We may be sure that if there were any great *increase* of land surface, the desert area also would be increased The same result would almost certainly follow if the present continents were drawn more closely together This seems to me a fatal flaw in Wegner s theory of continental drift For if, as Wegner held the continents were all originally joined together it is highly probable that the whole interior would have been a vast desert, with little or no life

But though the regular zone climates of the Earth are modified by the distribution of land and water and by altitude, he would be a rash man who would pronounce exactly what effect any serious redistribution would have That there have been great changes of climate in the past is certain although some periods such as the coal age seem to have been characterized by a uniform climate over a vast area persisting unchanged over a long period of time The difficulty is to know just what the distribution of sea and land was at that remote epoch The coal beds of the world indicate the swamps But where were the mountains whose rivers flowed into the swamps?

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We have already seen that to associate the greatest heat with the equatorial region is not quite in accordance with facts. Actually the great deserts occur in a wide belt which almost girdles the Earth just along, and in Asia largely outside, the tropic of Cancer. The greater land area north of the equator ensures that the largest and driest deserts shall be in the northern hemisphere. The north temperate zone contains about 8 million square miles more of land surface than the tropical zone; it contains nearly seven times the area of the south temperate zone. Hence the world's greatest desert belt lies mainly between 20 degrees and 40 degrees north latitude:

Asia	between 15° and 45°	North Latitude
Africa	„ 15° „ 35°	
N. America	„ 15° „ 45°	

Another narrower desert belt lies mainly south of the Tropic of Capricorn:

Africa	between 15° and 30°	South Latitude
S. America	„ 20° „ 40°	
Australia	„ 15° „ 35°	

Clearly, neither continuous heat alone, nor the proximity of the sea, nor the presence of lakes, will either make or unmake deserts, which are the result of drought, and depend upon the direction of hot and cold air currents.

Man however can initiate desert conditions within a generation. During the next 50 years the drive for more food may become intense, and irrigation in arid regions is likely to be in the forefront of human activities. But it would be a mistake to think that all the deserts of the world have only to be irrigated in order to produce crops, or even that the world's food supply can be greatly increased by a mere extension of irrigation. In many parts of the world the limit of irrigation has been nearly reached.

Irrigation is primarily the responsibility of skilled engineers who carry out the policy laid down by the government where it

can be applied It certainly enables crops to be raised on land previously sterile It produces arable land, but not pasture But while irrigation will undoubtedly be one means of increasing the food supply it will not of itself raise the standard of living of the peasants An expanding food supply means an expanding population and not much else

The long range implications of unlimited irrigation fall within the scope of the geographer, who promptly asks, is the total rainfall of the Earth s surface, supposing it to be everywhere evenly distributed, sufficient to convert all the desert of the world into a land flowing with milk and honey?

To that question it is impossible to give a complete answer at present, since we only have very rough estimates for the total rainfall of the Earth Yet the question is of more than academic interest, since it has some bearing on the limits of possible irrigation without violent reaction in other directions The reason for this is, that with the exception of a negligible amount of plutonic water stolen from the deeper crust, *all* the water used for irrigation purposes ultimately comes from the sky

Returning to our question, we may first note that if it means *exactly* what it says, the answer must be 'no For 3/4ths of the Earth s surface is water, and the precipitation over this area is probably less than over the remaining land quarter To equalize the rainfall over the entire surface therefore would mean diminishing the already apparently insufficient amount which falls on the land surface, consequently there would be not less but more desert If however we mean by the question a more equal distribution over the *land* of the rainfall already enjoyed by the land, it is impossible to give a categorical answer

We have already seen that there is a serious deficit of rain over 2/5ths of the land surface, rendering it unfit for agriculture Not less than 12 million square miles comes under this head The remaining 10 million square miles of desert land is too cold or too salt or too wet for agriculture Excess of rain — as on the west coasts of Scotland and Ireland — is as inimical to

agriculture as is a deficit; it gives rise to bogs, swamps and marshes. Fawcett[1] suggests that rainfall is excessive and harmful to agriculture if it exceeds the following amounts:

In cool temperate lands	50	inches per annum
„ warm „ „	80	„ „ „
„ hot „ „	100	„ „ „

This last figure seems rather low. There are many places in Eastern India, for example, where rice is cultivated although the annual rainfall is considerably in excess of 100 inches. But the areas concerned are negligible compared with the vast areas under rice where the rainfall is 75-90 inches, and Fawcett's figure is perhaps justified.

But in the tropical and sub-tropical belts the optimum rainfall is probably not far from the maximum, at least for rice, by reason of the great amount of evaporation and, in many places, of percolation and run-off. It would be dangerous to assume that in the tropics at any rate a 50-inch rainfall would serve as well as a 100-inch rainfall simply because with the latter we observe a heavy run-off Unless rainfall is both heavy and continuous, giving an almost saturated atmosphere, which prevails throughout most of the year, tropical evergreen rain forest could not exist. It would be replaced by a lower grade type of vegetation, with unforeseeable consequences.

But run-off and percolation are not wasted in mountainous regions, where the rainfall is often too high for agriculture. They give rise to streams and springs which irrigate crops lower down. Eventually the apparently surplus water finds its way to rivers, or to the plains, where it supplies wells To diminish the water supply to rivers by 50 per cent would have serious consequences, interfering with navigation (and thereby with distribution) and causing river blocks and, paradoxically, floods, due to lack of sufficient water to flush the channel.

The changes which can be brought about by altering the volume of a river is well illustrated by the Tarim which

[1] Professor C. B Fawcett, *Geographical Journal*, December 1930

formerly reached Lop Nor So much water is drawn off the upper course for irrigation that to-day the Tarim loses itself in the sands of the Taklimakan Desert west of Lop Nor As a result many villages have had to be abandoned

On the whole it would appear that to redistribute the rainfall more evenly over the land surface without increasing it, might merely result in robbing Peter to pay Paul Perhaps it would diminish the desert area, but at the same time it might easily reduce the habitability of desirable land and produce near-desert elsewhere Whatever good, or harm, it did it would completely change the human pattern of the globe

We must not forget however that much rain falls over the sea and is completely wasted It circulates from hydrosphere to atmosphere and back again without ever touching the lithosphere If this not inconsiderable fraction of the total rainfall could be diverted to the land surface, the answer to our question might be 'yes'

As already remarked the matter is of more than academic interest, for although it is not possible to increase or diminish the rainfall to any appreciable extent, such an inquiry does underline the fact that almost all water used for irrigation comes from the sky If rainfall over deserts cannot be increased, the engineer has a remedy in rivers and lakes, or artificial reservoirs, with flood control by means of dams and other works But for the reasons given the supply of available water is still limited by the total land surface rainfall, and it seems probable not only that there is insufficient to give all desert land a supply equivalent to Fawcett's minimum rainfall figures for agricultural land, but also that not much more desert can be irrigated without revolutionizing the world vegetation and hence the world's agricultural pattern

Compared with deserts, mountains, plains and even rivers are stable fixtures We know that they also are undergoing change all the time But they do not arise, or disappear, in the course of a few millenniums, as deserts do Deserts which look infinitely old are often geologically youthful Considerable areas in South

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invention of irrigation is ascribed to Babylon somewhere about 4000 B C Later, owing to wars and to neglect, the canal system fell to ruin

Some of the smaller desert regions of the world to day are the result of man's misguided activity, others are due to his neglect There has been no change of climate, only a loss of soil fertility Parts of the Middle West in the U S A (the 'dust bowl) and of the loess regions in North Western China are examples of man-made deserts in regions of precarious rainfall It is easy to tip the scale from just enough water to sustain one type of vegeta tion to not quite enough, resulting in a complete change in the type of vegetation, necessarily a degradation, as from forest to scrub or from scrub to poor grass, and so to desert Nor is the action reversible within any foreseeable time Man s reckless activities can set in motion changes of which it is difficult to foresee the end, and in a big way so also can nature

That in some parts of the world aridity is slowly increasing is suggested by the drying up of lakes, as in Tibet This might indicate a progressive desiccation, a continued excess of evapora tion over precipitation For though the climate of Tibet is cold, the low pressure greatly increases evaporation But there is no reason to think that the Earth as a whole is drying up, still less that there has been any great change of climate anywhere in the world during the historic period With 2/5ths of the land surface already too arid any great extension of the Earth's deserts would have the most serious results for mankind

It is questionable however whether the gradual desiccation of even a large tract of country would set a new wave of migration in motion Such migration 'waves of which there is evidence are much more likely to have been gradual, and to have con sisted of small bodies of men moving on intermittently through long periods of time We have nevertheless to account for the fact that men were filtering slowly into South East Asia at least two thousand years ago and probably long before that. But why should they have moved into the almost impenetrable jungles which must have covered the plains and still more the

Africa and America have become desert, in the sense that they will no longer support man, within a few decades through man's misguided activities. They are desert, not because of drought, but because every scrap of soil has been torn from them. The same energy, rightly directed, has converted desert into fields within an even shorter period.

Nor are the changes brought about by human activities confined to the immediate area; the effects may be widespread. For example unless steps are taken soon to change the methods of cultivation on India's North-East Frontier, in Assam and Burma, it is probable that within the next century many fertile valleys will become arid gorges, incapable of supporting any population at all, and almost devoid of vegetation, while the Brahmaputra, Chindwin and Irrawaddy may become unnavigable, their lower courses periodically subject to disastrous floods. Local changes of climate so brought about may start other changes in ever widening circles of action and reaction.

During the glacial age, perhaps as recently as 10,000 or 15,000 years ago, the Sahara was covered with grass, and was perhaps not unlike the Russian steppe to-day; at the same time the plain of northern Europe was tundra. The reason for this was that the southern advance of the polar ice cap pushed the belt of westerly winds from the Atlantic southwards, bringing ample rain to the Mediterranean basin and to North Africa. It must not be inferred however that so profound a cause would always be followed by so simple an effect as a mere shift of climate 10 degrees or 15 degrees in one direction; nor was the shift of the belt of westerlies accompanied by an equal southerly shift of the present arid belt. The desert in fact had no existence during the glacial age, and in the tropical belt of Africa alternate pluvial and dry periods correspond with the glacial and interglacial periods of the north temperate region (Leakey). Irak, now a desert region in spite of a fertile soil, was the granary of the ancient world. Great cities, Babylon, Nineveh and Ur, thanks to a system of irrigation canals flourished between Tigris and Euphrates where now the country is barren. Indeed the

But though man was already marked out into races long before he lived in the desert, the remains of ancient cultures, buried cities and abandoned sites, going back at least 5000 years, have been found in most of the old world-deserts One naturally asks why were these places abandoned unless because of a change of climate, an increasing dryness? However, the regions where these remains are found are still occupied, and local or temporary alterations of climate such as are continually occurring all over the world might account for an area being abandoned Oases too might change their position A shift of 100 miles in Central Asia would not be very much, and the Tarim river might easily increase or diminish that amount in length during a succession of wet or dry years At any rate there seems to be no convincing evidence that the climate of Central Asia has appreciably altered during the last 6000 or 7000 years, although much depends upon the interpretation of the evidence

One reason why the desert has left no distinguishing mark upon man is that very few deserts are to-day occupied by their original inhabitants The Australians may be real aborigines, so may be some of the Arab and Negro tribes In the cold desert regions, the Eskimo tribes are probably the original invaders The Australian black man and the Kalahari bush man no doubt owe their very survival to the fact that they live in the desert, though they have nothing in common Similarity of environment has brought about no similarity of feature, colour or any other character which serves to distinguish one race from another No man would choose to live in a desert if he could help it Whenever we find a population living in a desert or near desert region, we may be sure that it was either driven into the wilderness from some more fertile region by competition, or that the population itself has made the desert This may of course account for some of the migrations in Central Asia Desert conditions can be produced without any change of climate

It is worth noting that the cold deserts of the world are being invaded more and more by the white races, thanks to the breeding of wheat which will ripen within 90 days Both in Canada

mountains of tropical Asia, unless the regions from which they came could no longer support them? If it was not climatic change which drove them on what was it? Possibly the pressure of population behind them. The land which bore them may have been not too arid but too fertile! For an agricultural no less than for a pastoral people, grassland and parkland are preferable to jungle, which indeed can never support a pastoral people.

While deserts are being irrigated and cultivated in one region they are being created and extended in others by ruthless deforestation, over cultivation and over grazing. Desert is never very far from our doors. Even in Britain two consecutive summer droughts can so lower the water table that a partial failure of crops results.

No other feature of the land surface has had a greater influence on man than the desert. It has kept apart different races, and protected the weaker. Few of the great deserts had been crossed by Europeans before the nineteenth century, the empty quarter of Arabia was not crossed *till the twentieth century*. But deserts are no longer such serious obstacles as they were formerly. To-day man can fly over them, and the motor car can go where man and beast would perish. Nevertheless, they are still in a military sense formidable obstacles, just as they were to Alexander twenty three centuries ago.

Every desert region has its own peculiar fauna and flora. However, desert vegetation, from whatever part of the world it comes, has a certain appearance which stamps it as of the desert. The same cannot be said of desert man, and it appears that man has not occupied the arid lands long enough for the desert to have left any special mark on him. What could be more different than the Badowin and the Australian aborigine! This alone would seem to be good evidence for deserts being geologically modern, although if that is so, it is difficult to see how desert vegetation came to be so well adapted, and along the same general lines, the world over! Morphological change in the vegetable kingdom must have taken place rather rapidly without any great change of floral structure.

IX

RIVERS

We have seen that no sooner does land appear, and air, sea and land come into collision, than, under the influence of the sun's heat, atmosphere and hydrosphere assault it. The land suffers. So long as there was no land, comparative peace reigned. Even the tides had nothing to do except rise and fall. Crust below the 1000 fathom line suffered not even a sea change, for neither tide nor currents have any appreciable effect at that depth. Energy derived from the sun's heat varying from equator to poles, and disturbed only by the rotation of the earth, kept currents gently moving in the outer shells; but it needed the presence of solid matter to gear up the machine. Thereafter a much more serious inequality of heating took place, and quickly made itself felt.

The first land raised from the sea floor was raw crust; and no doubt the crust was a good deal thinner and certainly rawer then than it is to-day. Now after the lapse of a thousand million years or more any new land raised up is probably coastal shelf, that is, previously drowned land, or else volcanic. Also the present continents have to be sustained, since we know that they are being continuously worn down by rivers and weather. The crust was no doubt originally forced up in the form of mountains. But since the first sedimentary rocks were laid down it has been uplifted also as plains and plateaux. No sooner does land rise above the sea than it attracts cloud, or more accurately, cloud condenses round it, rain falls and the first rivers are born.

It is obvious then that mountains, plains — some plains at any rate — and rivers are primary geographical features. Many other land forms, such as valleys, gorges, lake basins, deserts, are secondary or derived features. I propose here to discuss a

and in Siberia agriculture has advanced northwards far beyond the point where it stopped in the nineteenth century. But it cannot move northwards indefinitely and the limit somewhere south of the July isotherm of 50° F. has probably been reached. In the same way drought-resistant crops have been introduced into Australia and have pushed back the fringe of the desert where irrigation has proved impossible.

But though deserts have always formed an impassable barrier against large-scale migration, they have rarely formed a barrier to small parties of men and animals wishing to cross them. The Australian desert was never crossed because Australia had no mammals; and the American and South African deserts were probably never crossed owing to the absence of the camel. But all the old-world deserts were crossed again and again. Besides, men could move round or parallel to them. Real desert however has never supported any population and large areas in North Africa, Arabia, Central Asia and Tibet have no population to-day. The migrations of peoples in Asia and Africa have always been round the edges of the desert.

The onset of desert conditions is sometimes gradual through transition zones, arid, near-desert to complete desert. But it is often abrupt as when a desert begins on the sea coast or a range of mountains intercepts the rain-bearing winds, giving vegetation on the windward slope and desert on the lee slope: the best example of this is the Himalaya, which stops the south-west monsoon. When one crosses the Himalaya into Tibet from Assam, Bhutan or Sikkim, the contrast on north and south sides of the passes from forest to semi-desert is startlingly abrupt.

During the next decade the question of deserts and irrigation, of increasing the world's food supply, is likely to come to the fore. The spectre of world famine on an unprecedented scale hovers in the background. The geographer is not concerned with economics, but he cannot altogether ignore its implications. He can help the planner, but only if the planner will listen to his advice and weigh his evidence fairly against his own theoretical panaceas.

being upset and as slowly readjusting itself, so that no violent movements are set up, unless over a very limited area But if we imagine a great and steady increase in the land area, a stage might eventually be reached when there was not so to speak enough sea to maintain itself as sea Evaporation, due to the hot air rising off the land, might become so great, currents so turbulent, that practically all the water of the earth could exist only in the form of vapour, with possibly a number of rivers flowing through deserts and, like the Tarim, losing themselves in the sands or ending in large salt lakes like the Caspian Sea, scattered over the surface and ever dwindling in area under the sun's heat

Fortunately our Earth started with such an ample supply of water that even supposing the atmosphere to be everywhere and always saturated, it could not at present temperatures absorb more than a small fraction of the hydrosphere. Moreover, were it possible for the atmosphere everywhere to be always fully saturated — and as long as there is both land and sea with consequent unequal heating that is impossible — the only result would be constant rain with the production of more rivers The Earth would be surrounded by a perpetual mist bath, forming a sort of extra shell The only way in which the Earth could absorb the entire sea would be for the crust and sub crust to take it up

Nor are the visible seas and rivers the total circulating water on the Earth's surface A vast but unknown quantity circulates, as we have already noted, underground, not in the core where it could not exist, but in the crust. There is then no probability of the Earth drying up, as the moon has dried up, no danger of its gaseous shell flying off into space, taking with it all water vapour, as has happened apparently on the moon For the moon has no atmosphere — hence no 'weather'

Let us return to actual rivers

Gazetteers usually list a few of the world's longest rivers, and we are all familiar with such names as Mississippi, Nile, Amazon and Yangtze Kiang because of their great length But length

few prominent geographical features, both primary and secondary, in rather more detail. Let us therefore begin with rivers.

With the emergence of land rain begins to fall and rivers are born; no sooner do rivers begin to flow than the distribution and shape of the land begins to change. Of the many forces which work upon the face of the land, rivers are the most powerful. In course of time they shift large chunks of the Earth's crust from one part of the surface to another. This redistribution of weight may, even after the lapse of millions of years, be too insignificant to affect the balance of the Earth as a whole, but it certainly produces local effects. Through the long ages during which rivers have flowed over the land surface, not only has a great deal of crust suffered demolition and the debris been removed, but it has been reconstructed elsewhere. This has happened again and again, often using the same materials several times over. Land has appeared, has been destroyed, returned to stock for alteration and repairs, to reappear in brand new form elsewhere.

The total volume of moving water in the rivers of the world is enormous. There are more than fifty rivers one thousand or more miles in length. This water is working and bringing about changes all the time. In the course of ages, the changes wrought are incalculable.

If there were more land than there is — say twice the area, there might be more and even larger rivers than exist to-day; but that is by no means certain. There would inevitably be more desert — unless the extra land was scattered in the form of large islands over the Atlantic and Pacific oceans. What the effect of that would be in altering the direction and intensity of currents, no man can say. Rivers and deserts depend on climate, and climate depends largely on sea and air currents. More exactly, climate depends on a certain uneasy balance between land and sea, which is continuously though slowly

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north, while to the west lay impassable mountains. For long the only route into the heart of China lay up the Yangtze river. The Irrawaddy and Mekong are other examples. In mountainous New Guinea both the Fly and the Sepik offer possible routes into the interior, which for so long defied explorers.

We have already observed that no two rivers are alike. However they may be roughly classified in two groups, those of each group having some features in common. Thus we may recognize rivers whose waters are derived entirely from rain, and those which receive much of their water from glaciers. Alternatively we have the rivers of a monsoon climate, like those of South-East Asia, with its heavy summer rainfall, secondly those of temperate climates which receive most of their flood water in winter, and lastly Arctic rivers which are largely frozen over in winter. What proportion of the rain which falls within its catchment area finds its way to the sea—that is the run-off—varies greatly. Evaporation, percolation, and the needs of vegetation absorb much of the rain. Evaporation in a hot dry climate may be so great that the river never reaches the sea at all, or even a lake. The Nile flows for 1500 miles through a hot rainless desert, but already contains so great a volume of water when it enters the desert region that it is able to keep its channel open and reach the sea even during the low water season. The Tarim, on the other hand, though 1500 miles long, does not even empty itself into a lake, it dwindles, dries up and loses itself in the thirsty sands of the Taklamakan Desert. This is partly due to the loss of water in its upper course drawn off for irrigation, but mainly to evaporation and percolation. The Syr Darya and Amu Darya, two other rivers of arid Central Asia, each 1500 miles in length, reach the great inland Sea of Aral, which is itself drying up. Thus a river which flows for a long distance through deserts may disappear like the Tarim, or lose itself in salt lakes like some of the South Australian rivers, or even reach the sea as the Nile does. But it is bound to lose a vast quantity of water by evaporation. Many small Andine rivers

is perhaps the least significant, the most uninteresting feature of a river The geographer, surveying the world, finds no two rivers alike except perhaps in length Each must be studied apart, although of course it is an advantage to know something about the work and characteristics of rivers in general before intensively studying one river in particular

To primitive man, rivers must have been something of an obstacle Arrived at a big river, a wandering tribe no doubt moved up or down stream and made no attempt to cross it In time it supplied the tribe with food, besides affording likely camping places along its banks In hilly districts, caves are associated with rivers particularly in the chalk hills of Europe, as for instance in the Somme Valley, and for thousands of years early man in Europe lived in such caves, above a river

The next part played by rivers in the history of man was no doubt as a means of communication, though they do not seem to have been deliberately used for this purpose until much later Man used river valleys as the line of least resistance But different tribes, often mutually hostile, settled along the banks, and there could have been only infrequent comings and goings Later he built boats and navigated the rivers To this day different tribes having little or no communication with one another inhabit particular stretches of rivers like the Amazon and Orinoco But in course of time men no doubt followed rivers up towards the high pastures, and down to the sea, seeking new settlements

In many parts of the world, notably in Africa, rivers offer the only practicable routes into the interior of the continent The reason why Africa for so long remained the Dark Continent was that nobody thought of trying to sail up its rivers, or if they did try, they failed Nearly all African rivers, rising on the plateau, are broken not far from their mouths by rapids For 3000 years men sailed round the African continent without finding means of ingress though both Niger and Congo afforded possible routes to the interior Similarly China was protected on the

on the outside of a bend, adding land on the inside. This gives rise to disputes about the ownership of land, and sometimes concerning the responsibility for losses incurred. Thus rivers do not make good international frontiers although often popularly regarded as 'natural' frontiers.

Rivers are in the first place destroyers of land, but at the same time they are also instrumental in changing new lands for old, though they could not do this without other help. Their tendency is to level out mountains, to plane down the world to a uniform dead level, and this feat they would in time accomplish — would long ago have accomplished, but for the forces in opposition, tending to uplift the land.

As we know, the sea could quite easily swallow up all the land if there were any means of transporting it to the great ocean basins, and dumping it there. But it is very doubtful whether rivers ever transport silt more than 200 or 300 miles from the coast; they unload and spread it on the continental shelf, in shallow water. All else remaining static, the shelf would in time become land, a flat plain or swamp, and then perhaps the advancing river might transport silt a further step from the shelf's seaward edge towards the deep basin. It *might*. But it is more probable that it would only form a vast area of deltaic swamp, not unlike the Sunderbans to-day, and there lose so much water by evaporation that the further transport of silt would be impossible. No doubt a state of equilibrium between redistribution of land and evaporation of the river water would be reached long before all the land could be carried far out to sea, though not perhaps before it had all been planed down to a uniform level.

A river is, from this point of view, simply a removal agency. But from another point of view it is also a repairing agency. It refreshes the old land each year by spreading a layer of fertile silt over its flood plain, thus rejuvenating the exhausted soil. A river also irrigates its delta, subdividing to cover an extensive tract of country. Thus on the plains of Lower Burma, Siam and other countries, a strip of evergreen forest will mark the line of

lose themselves in the swamps, deserts and salt lakes of Bolivia and Peru.

Rivers which have their source among glaciers, or which contain a large amount of snow water, show a big rise in spring and early summer, due to the melting of the snows. The Himalayan and Tibetan rivers, Indus, Ganges, Brahmaputra, and the rivers of South-East Asia, Irrawaddy, Salween and Mekong all have their sources amongst glaciers and show this spring rise. But with the exception of the Indus, which flows mostly through arid country with only a small rainfall, the first rise due to snow-melt at the source is concealed later by an equally large rise due to the monsoon rains which drench their middle and lower courses. This spring-summer rise on the Irrawaddy, a river only about 1500 miles long, but with a great volume of water, is very conspicuous The headwaters of the Irrawaddy rise among many small glaciers and snow beds on the Tibetan and Chinese frontiers, a region of exceptionally heavy snowfall down to 9000 feet altitude — the average height of the mountains at the sources of the Irrawaddy is 12,000-14,000 feet. The snow begins to melt in March, and the river at once begins to rise. In May or June the monsoon breaks, and the rise caused by snow-melt is immediately increased by that because of heavy rainfall. Both sources are cut off during the winter so that the difference between high and low water is very marked. At andno, 900 miles from the sea, it averages 30 feet. The Nile at rivep rises 23 feet — its annual rise and fall has been recorded seeking years.

In mivers which flood heavily — as most rivers do — are only pr change their course, with disastrous results. In 1852 reason ow River of China changed its course at a point 300 that nobn the sea, flowing north-east instead of south-east, its try, they h being 300 miles from the old mouth. This was perare brokextreme case. Many of the great rivers of Southern men saileover, inundate the low-lying plains at frequent interof ingress, re is always the danger of a permanent change of routes to thi rivers are perpetually cutting away their banks

each channel in a region of deciduous forest The evergreen forest is able to maintain itself throughout the hot season, thanks to water supplied to the soil by the stream

After man had settled along their banks — and doubtless suffered many disasters in countries where the rivers rise 30 or 40 feet during the rainy season — came irrigation It is noteworthy that the first river valleys to be settled were situated in almost rainless country, here irrigation was absolutely necessary to maintain life Irrigation therefore is one of the most ancient uses to which rivers were put, but only a few rivers, such as Nile, Tigris, Euphrates, Amu Darya, Syr Darya, Tarim and Indus, flowing through deserts nourished these early civilizations Many ingenious simple machines were constructed to lift the water from the river to the top of the high bank and distribute it to the fields Some of them, such as the Persian wheel, the treadmills of Western China, the water filled skins dragged up by bullocks in India and others are in use to-day

For at least 6000 years man has known the value of rivers for water storage, irrigation and annual fertilization of the soil And for nearly as long he has made use of rivers for purposes of trade Not till the nineteenth century did he realize that they had another use — as a source of power

During the last hundred years man has begun to study rivers closely in all parts of the world, and at all seasons He has come to realize that rivers are too irresponsible, too irregular and unpredictable in their actions, too violent in temper and too inconstant to be trusted To get the best out of them they need to be harnessed and controlled, and not only for that, but even more in order to curb their ferocity and prevent the enormous damage they are capable of inflicting They need to be held in leash that their strength may be conserved and used to good purpose The tremendous importance of its rivers, not only to an agricultural, but also to an industrial state, is beginning to dawn on man In the future, states which control great rivers will start with an incalculable advantage To say that future

wars may be waged for such control is only to utter a timely warning

On the other hand rivers like the Hwang Ho and the Yangtze, the Ganges and Brahmaputra, and others, which are or can be a scourge to mankind should obviously be brought under control At present political difficulties arise when a river flows through several independent states, for action taken in one state may adversely affect the use of the river above and below Unless all share alike in the benefits trouble is bound to arise

Before a big river can be successfully harnessed, it needs to be watched and intensively studied, on the plains at least, during a complete cycle, which may be anything from 30 to 50 years Very few rivers have been studied for anything like 50 years But America has shown what river control really means, and what it can do The Tennessee Valley Association has won a world wide reputation In the words of the late President Roosevelt 'The T V A is a Corporation charged with the powers of Government whose chief terms of reference are flood control, power (hydro-electric), reduction of soil erosion, navigation water storage and irrigation' In thirty years the T V A has transformed the Tennessee Valley from one of the most back ward to one of the most prosperous, happy and go ahead dis tricts in the U S A Twenty five years ago the inhabitants, subject to calamitous floods, poverty stricken and wretched, numbered fewer than one million To day they number more than two and a half million The T V A concerns itself with regional planning on a bold scale — what to-day would be called Reconstruction It now holds together and conserves all natural resources, controls soil erosion (thereby maintaining fertility and preventing floods), preserves wild life, keeps open the river channel for navigation, lessens pollution, looks after fisheries, distributes and produces cheap power A big programme indeed and a model for other countries Yet it is clear that this is only a small experiment in control of the world's rivers When rivers like the Amazon, Yangtze, Hwang Ho,

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carry all the flood water, although this may be partly due to the destruction of vegetation, especially forest, along its banks In the monsoon countries, before the coming of man, the banks, deltas and flood plains of the great rivers were covered with dense evergreen jungle, often impenetrable, or with swamp jungle Early man, whose only tools were chipped stones, could not clear the jungle Not till he possessed metal tools could he do so Hence in spite of many advantages which the monsoon rivers offer, civilization had no chance to develop in the tropics

Once he was civilized, the tropics had much to offer man But clearly he found the best conditions for advancement in the arid lands of the Middle East and of Central Asia Nor were the arid regions of other countries to his liking In North America, the poverty of animals and plants fit for domestication may have been a deterrent, elsewhere the absence of suitable rivers — or the absence of man himself The unique feature in the colonization of North America is the success with which man has introduced domestic animals and plants

As we know now — and as Herodotus more than 2200 years ago guessed, the reason why in this rainless region the Nile rises in summer is because of the melting of the snows many hundreds of miles away, and also because of the heavy rainfall on the Abyssinian highlands Elsewhere, but later than in the Middle East by perhaps 2000 years, a civilization arose in China, in the valley of the Hwang Ho, another region of slight rainfall with a hot summer and cold winter

Broadly speaking, the behaviour of a river depends largely on climatic conditions within its catchment area, and especially on rainfall But a river 3000 miles or more long is certain to pass through several climatic regions in each of which the conditions are different

The course of a long river, say the Mekong, may be conveniently divided into sections as follows (i) mouth and delta, (ii) plains section, comprising the navigable part and the in-

Congo, Ganges, Brahmaputra, Irrawaddy, Salween, Indus, Amur and Niger, to mention a few, are taken in hand, what may not the world hope for?

Rivers are never idle They are always at work and always changing, not for a year, not for a month, not even for a day do they remain the same Mountains, plains, even seas are relatively stable, but not rivers On a small scale, a great river has the same effect as the sea in modifying the climate locally In the hot weather in Eastern India there is always a breeze — not necessarily a cool one — blowing on the two or three mile wide Brahmaputra

River banks must have provided some of the earliest settlements for man Tired of wandering through the forests and across the bitter wastes, he must have rejoiced on reaching the banks of a river or a lake. In the Neolithic age one of the earliest centres of civilization was the lower valley of the Nile But even earlier were the settlements in the valleys of Tigris and Euphrates and probably of the Indus All these places had certain advantages They lay just outside the tropics in the present dry belt of the world, where the annual rainfall is scanty (5-10 in), the summers hot and long and the winters cool and short Almost anything will grow if it gets enough water, but irrigation is essential, without irrigation almost nothing will grow — that is, the country is semi desert

One of the most surprising things about this arid region is that the rivers have much in common with the rivers of the monsoon countries — they rise and fall many feet, summer and winter, but with a difference In the Middle East the rise corresponds with the hot dry weather, not with the rainy season as in the monsoon belt The fall occurs in the cold and slightly wet winter, not with the fine warm winter of the mon soon belt, too optimistically called the 'cold weather.

This rhythmic rise and fall of the desert rivers, alternately flooding and exposing great areas of flat plain, allows of periodic cultivation as on the deltas of the monsoon rivers It may be noted that on the plains the river bed is never large enough to

carry all the flood water, although this may be partly due to the destruction of vegetation, especially forest, along its banks In the monsoon countries, before the coming of man, the banks, deltas and flood plains of the great rivers were covered with dense evergreen jungle, often impenetrable, or with swamp jungle Early man, whose only tools were chipped stones, could not clear the jungle Not till he possessed metal tools could he do so Hence in spite of many advantages which the monsoon rivers offer, civilization had no chance to develop in the tropics

Once he was civilized, the tropics had much to offer man But clearly he found the best conditions for advancement in the arid lands of the Middle East and of Central Asia Nor were the arid regions of other countries to his liking In North America, the poverty of animals and plants fit for domestication may have been a deterrent, elsewhere the absence of suitable rivers — or the absence of man himself The unique feature in the colonization of North America is the success with which man has introduced domestic animals and plants

As we know now — and as Herodotus more than 2200 years ago guessed, the reason why in this rainless region the Nile rises in summer is because of the melting of the snows many hundreds of miles away, and also because of the heavy rainfall on the Abyssinian highlands Elsewhere, but later than in the Middle East by perhaps 2000 years, a civilization arose in China, in the valley of the Hwang Ho, another region of slight rainfall with a hot summer and cold winter

Broadly speaking, the behaviour of a river depends largely on climatic conditions within its catchment area, and especially on rainfall But a river 3000 miles or more long is certain to pass through several climatic regions in each of which the conditions are different

The course of a long river, say the Mekong, may be conveniently divided into sections as follows (i) mouth and delta, (ii) plains section, comprising the navigable part and the in-

Congo, Ganges, Brahmaputra, Irrawaddy, Salween, Indus, Amur and Niger, to mention a few, are taken in hand, what may not the world hope for?

Rivers are never idle. They are always at work and always changing, not for a year, not for a month, not even for a day do they remain the same. Mountains, plains, even seas are relatively stable, but not rivers. On a small scale, a great river has the same effect as the sea in modifying the climate locally. In the hot weather in Eastern India there is always a breeze — not necessarily a cool one — blowing on the two or three mile wide Brahmaputra.

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X

GORGES

In many parts of the world rivers break through mountain ranges to form gorges It seems at first sight curious that a river should rise north of say the Himalaya and flow *through* the range which appears to place an insuperable barrier in its way The popular idea of a watershed is a mountain chain with rivers rising on either side of it, like streams flowing down a pent house roof Peaks are supposed to stand on the more or less straight crest line and dominate the rivers flowing down either side This rarely happens in nature Even when the rainfall is the same on either side of the range, the rivers work backwards from their heads, biting into the chain between the peaks, so that they come to rise *behind* the peaks The watershed then becomes zigzag

But when the rainfall on one side of the mountain chain is much greater than it is on the other, the mountains in fact forming a rain screen, as happens with some of the greatest mountain ranges in the world, including the Himalaya and the Andes, the rivers on the rainward flank cut backwards more rapidly than those on the drier flank All the large streams which flow down the southern face of the Himalaya rise well behind the line of highest peaks on the main range Indian rivers like the Indus, Sutlej and Brahmaputra rise in Tibet far behind not only the Himalaya but also other ranges north of the Himalayas All of them break through the mountains in tremendous gorges, owing to their power of cutting back rapidly by head erosion and capturing more water, thereby increasing their strength

There is a startling contrast between the gorge of the Indus at the north western end of the Himalaya, and the gorge of the Brahmaputra at the north eastern end Alike in many respects,

habited valley and flood plain above the delta; (iii) hill section, less thickly populated, navigable only for country boats; (iv) mountain section, sparsely populated, unnavigable, with rapids and falls; and (v) source. There may or may not be gorges on the last three sections; and we may now proceed to consider what manner of feature these gorges are.

safer than these slit trenches! The ranges enclosing and separating them culminate in snow peaks over 21,000 feet high and have all the appearance of narrow ranges which strike north and south, that is parallel to the rivers

Is this the correct interpretation? Are things what they seem here?

Now it is obvious that a great mountain range such as the Himalaya, which consists not of a single range but of a number of more or less parallel ranges rising gradually from the plain to greater and greater heights, has breadth as well as height The breadth of the Cordillera in Ecuador is about 150 200 miles, of the Rocky Mountains in Montana about 250 300 miles, of the Himalaya practically throughout its length about 200 miles

If a river cuts a gorge 200 miles in length straight across the Himalaya, one sees simply a gorge crossing the axis of the main range and the axes of its satellite ranges But if *two* rivers cut parallel gorges close together they will sever as with a knife a strip of mountain from the main range, this strip will be 200 miles long and say 50 miles wide, supposing the rivers to be 50 miles apart, and it will in fact look very much like a mountain range 200 miles long, its strike being at right angles to that of the original range If three rivers behave in the same way there will be two parallel ranges isolated from the main range and at right angles to it, and the number of rivers might be increased until all visible connection between the main (transverse) range and the secondary (meridional) ranges had been lost This would certainly happen if the gap between the two ends of the range now occupied by three rivers crossing its axis, and by three secondary ranges also at right angles, exceeded a hundred miles or so, for it would be impossible to link up the two ends of the main range by eye alone The only clue now as to whether these meridional strips are original mountain uplifts or have been blocked out of the transverse chain by rivers is their geological structure This in the region referred to has not yet been unravelled

the former occurs in an arid region of very limited rainfall, the latter in one of the wettest regions in the world As a result the cliffs of the Indus gorge are almost bare of vegetation, certainly of trees, whereas those of the Brahmaputra or Tsangpo gorges are covered with magnificent forests, in which grow vast numbers of rhododendrons of all colours

I have necessarily over simplified the matter in order to describe how gorges may be formed But mountain ranges are never simple The Himalaya for example comprises not a single range but a series of parallel ranges, each rising higher than the one behind and separated from it by a deep valley Thus, starting from the plains we have first the foothills, then the outer ranges, followed by the middle ranges, and finally the inner ranges culminating in the crest line Rivers rising on the rainward flank, that is on the Indian plains side of each separate range, cut backwards into the valley behind and presently capture its drainage, so that Himalayan rivers, in regions of heavy rainfall at least, tend to flow for considerable distances east or west parallel to the range before they turn southwards

Thus rivers breaking across the axis of a mountain range such as the Himalaya, at right angles to the strike, tend to flow in deep gorges, and we may reasonably ask alternatively whether the existence of a gorge is proof of the existence of a mountain range whose strike is at right angles to the river The question arises primarily in connection with the gorges of the Salween river (as also of the Mekong and Yangtze Kiang, as well as of several lesser rivers) on the Sino Tibetan borderland These three rivers rise over a wide area of mountainous country far up on the Tibetan plateau In about latitude 32 degrees they begin to converge Between latitude 30 degrees and latitude 27 degrees they flow parallel to one another, for a distance of 200 miles within a belt of country 50 60 miles wide before the Yangtze turns away, the Mekong and Salween continue to follow parallel courses for another 100 miles All three rivers, especially the Salween, flow in profound gorges In the modern world of fast aircraft dropping 10 ton bombs, no place could be

doubling back on themselves in a confusing manner. The Yangtze itself makes a double hairpin bend. This would be almost incomprehensible did we not know that the whole region, which was formerly a plateau or series of plateaux, lay under an ice sheet during the glacial age. The inequalities of the plateau, by now so deeply eroded as to leave great mountain ranges standing up between the valleys must then have been almost insignificant; they were hidden beneath a vast ice sheet. As the ice sheet melted, leaving behind glaciers in the valleys, and as the glaciers themselves melted at unequal rates, a certain drainage pattern was fixed on the country. But as the glaciers began to disappear altogether and rivers more and more took up the work of erosion, a new pattern evolved which did not quite fit the old ice pattern, traced several thousand feet higher up. The present river pattern, e.g. of the upper Irrawaddy, seems to be a combination of the two, glacier and river drainage.

Gorges are formed in other ways than that described above. The Yangtze gorges, not those just referred to but the ones between Chungking and Ichang, perhaps the best known gorges in the world, seem to have been formed by an uplift of the surrounding country persisting while the river was digging its bed, and at about the same speed. There are 400 miles of gorges here. Other river gorges, generally shorter, occur in many parts of the world. Most small rivers in mountain regions flow through gorges.

In North America, the gorges of the Columbia river and of the Colorado, are world famous; hardly less so is the Niagara gorge. But there is nothing to touch the great gorge of the Brahmaputra or Tsangpo of Tibet for dynamic scenery. It is the one gorge in the world where one can stand amidst sub-tropical forest by the river, some 5000 feet above sea-level, and gaze almost sheer upwards to see everlasting snow and ice 15,000 feet above; and in between, tier above tier of forest changing from temperate broad-leafed to conifer, from conifer to rhododendron scrub, to alpine, and finally to everlasting snow. Down below the river plunges yet deeper into

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There is however another test which may be applied The visible proof of a mountain chain is the alignment of its high peaks which gives a clue to the strike of the chain Unfortunately the distribution of the high peaks along the Sino-Tibetan border land is no better known than is its geological structure Many of the peaks have never even been seen by Europeans, and of those that have, neither their positions nor heights are known with sufficient accuracy It may be remarked however that the mere fact of there being a series of high peaks on a meridional alignment is not in itself proof of original structure nor does it vitiate the possibility of the meridional range being an isolated block cut out of the transverse range, for the high peaks may fit in with those of two or more parallel ranges on the flanks belonging to the transverse system That is exactly what the snow peaks on the Yunnan Tibet frontier appear to do

There is another feature of these river gorges seen even more clearly in the gorges of the Irrawaddy further west and probably also in the Brahmaputra gorge, which calls for comment, namely their dual nature Each valley was first ploughed in a plateau by glaciers In the floor of the wide furrow, water then made a deep incision as though with a sharp knife Thus each valley is double, a valley within a trough No glaciers reach any of the rivers to-day, except in the gorge of the Brahmaputra where one glacier was seen to come right down to the water's edge But in the Mekong gorges and probably also in those of the Salween glaciers still reach the edge of the upper trough.

The gradient in these gorges is always much greater than on the plateau where the rivers rise, or on the plains to which they descend All the Tibetan rivers — Indus, Sutlej, Brahmaputra Salween Mekong Yangtze, Hwang Ho—descend thousands of feet through gorges hundreds of miles in length Even the Irrawaddy, the main branch of which rises just within Tibet, descends 12 000 feet in 200 miles

Several of the rivers between the Eastern Himalaya and Western China follow erratic courses even through the gorges,

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the mountains as though into the very bowels of the earth with a roar which fills the gorge with thunder

But it is as affording passage for migrating tribes through the great mountain ranges that the river gorges of South East Asia are of special interest to the geographer Nearly all the modern inhabitants of tropical Asia came from the north probably from Central Asia, and it seems certain that most of them — Malays, Burmese, Siamese and many of the hill tribes — came down the valleys and gorges of the Salween, Mekong and other rivers, no doubt during the last 2000 or 3000 years Other tribes must have preceded them These river gorges, from the Brahmaputra in the west to the Yangtze in the east, afford the only link, other than the high passes between the Central Asian basin and the fertile plains and deltas south of the mountain barrier

We have already discussed possible reasons for these migrations It will be enough to repeat that we do not know the real reason Modern geographers believe that there has been no great change in the climate of Central Asia within historic times — *say within the last 5000 years It is suggested that the* desert conditions of the Tarim basin for example are due not to change of climate but to the failure of the river, owing to retreat of the glaciers amongst which the river rises But this merely transfers desiccation from the basin to the mountains, for how otherwise should the glaciers shrink! And if the mountains receive less precipitation, the central basin is likely to receive still less

However, so far as the migrations we are considering are concerned they may well have begun more than 5000 years ago, and continued for thousands of years

But why, it may be asked, did the tribes not move eastwards into the fertile valleys of China and the great plains? The answer is that already the pressure was from Central China outwards A great civilization was springing up in Eastern China, in the valleys of the Yellow River and of the Yangtze A bulwark was being erected against the barbarians of the western mountains Indeed Nature herself had seen to it that on

the west and north China was protected by 3000 miles of formidable mountains and deserts, and anyone coming from Central Asia must first cross these It was easier to follow the rivers southwards through the gorges than travel eastwards But the mountains to the south are like a spider's web, and many were caught up on the way and entangled in the sticky jungle, isolated from the main body and from each other And while the main body no doubt pressed on steadily southwards, smaller patrols broke away to east and west, or even doubled back on their tracks Every main body shed bits as it advanced

In some such way we can perhaps account for the extraordinary mixture of tribes which inhabit the mountains between India and China. It seems certain that these narrow river gorges which pierce the mountain barrier of a desert region have admitted the refugees to the coastal plains To-day mule-borne trade passes up and down them as of old

Where rivers flow through gorges they offer little scope for irrigation But they afford unlimited power As to navigation, the Yangtze gorges, navigable throughout their length, are perhaps unique, though it must be remembered that the Yangtze here falls only 100 feet in 400 miles Even the third defile — a very minor gorge — of the Irrawaddy between Bhamo and Myitkyina has been navigated only by small launches, and that only in the low-water season The Salween and the Hwang Ho are probably the two largest and longest unnavigable rivers in the world, and that for quite different reasons

Rivers flowing in gorges can never overflow their banks But they can be the cause of flooding on the plains lower down, by piling up the excess water It is here that great dams would probably be most effective

XI

DELTAS, AND A DIGRESSION

DELTAS, which are plains formed by rivers meeting the sea, are areas of deposition Most rivers, especially tropical rivers in regions of heavy periodic rains form deltas, but some form estuaries If the lower end of the valley is gradually sinking or if there is combined river and sea erosion, that is to say if there are strong currents along the coast, an estuary will be formed The formation of deltas appears to depend almost entirely on the quantity of silt carried by the river If this exceeds 0 1 per cent (by weight) of the total, a delta almost inevitably results, and this although periodically the silt content falls well below that figure (as during the dry weather in a monsoon climate) The great estuaries of the St Lawrence, Amazon and Plate are probably all drowned valleys, as is the Thames estuary

In the tropical zone, deltas are amongst the most thickly populated regions in the world, outside the industrial areas As river control expands and cultivation becomes more intensive, they are likely to become even more thickly populated, and of even greater importance as food producing areas Half of the agricultural population of South East Asia lives on the deltas of seven rivers and their associated streams namely Ganges, Brahmaputra (India), Irrawaddy, Sittang (Burma), Menan (Siam), Mekong, Red River (Indo-China) and West River (China) Their potential food production is an important factor in the future of Asia and of the world Yet compared with the arid deltas of the Nile and Indus these wet deltas have not long been inhabited by civilized man, the first six almost certainly for less than 2000 years Before that they were largely covered with mangrove and swamp jungle, as much of the Sunderbans (Ganges delta) is to-day

The Nile delta, though it has had great influence in the world as the seat of one of the earliest civilizations, is small,

covering only about 4000 square miles, in spite of the great length of the river. But much of the water is drawn off above the delta, and much of the mud deposited in the swamps of the Sudan when the river rises. Length of river indeed is no indication of size of delta. The Ganges-Brahmaputra delta is the largest in the world, covering fifteen or twenty thousand square miles. Evaporation from so great a surface in the hot climate of Bengal is enormous, and the more water is evaporated the more readily what remains drops its mud, and the faster the land advances on the sea.

The control of this great system of rivers for the same purpose as the Tennessee Valley Association (T.V.A.) was organized would be a tremendous undertaking, but it would pay handsomely in the long run. Indeed, it is impossible to set limits to what might be achieved with modern machinery, methods and knowledge. Deltas, as vital food-producing areas, are likely to come in for much attention during the next half century. It is even possible to conceive of deltas artificially brought into existence, or written off.

For example, it would be quite possible to divert the Mekong river, more than 2000 miles from its mouth, and turn it into the Salween, with unpredictable results. The delta of the Mekong, now the granary of Annam, would no doubt disappear; but the Tonle Sap, a large lake in Cambodia which takes much of the overflow of the Mekong in the flood season, would disappear too. What would happen in the lower Salween valley it is impossible to say. Moulmein would no doubt be obliterated but might be rebuilt on higher ground; but the scouring of the bed of the Salween might make that river navigable for several hundred miles.

The Salween, which has not even a delta, is a peculiarly useless river, being already unnavigable within a hundred miles of its mouth in spite of its 2000 miles length. Moreover the bar at its mouth prevents large vessels reaching Moulmein. It would hardly be missed in the economy of Burma. The Mekong, on the other hand, is a useful river, being navigable

for 600 miles from the sea and, with interruptions, for several hundred miles beyond that. Also it has a delta. It might therefore be a better plan to turn the Salween into the Mekong, and flush the rather troublesome channel of the latter river, besides giving deeper water in the middle reaches. Unfortunately it is not a reversible project; and while it would be perfectly feasible to divert the Mekong into the Salween flowing 15 miles to the east and 1200 feet below, it would be practically impossible to make the Salween flow uphill into the Mekong!

That the idea is not altogether fanciful is suggested by the fact that the Orinoco, about a thousand miles from its mouth, is connected with the head waters of the Amazon by a natural channel, the Casciare Channel. Thus one can enter the mouth of the Orinoco, proceed inland a thousand miles, and reach the Rio Negro 700 miles above Manos, which is a thousand miles -- by ocean steamer -- from the mouth of the Amazon.

Another hydraulic improvement which might be achieved without great difficulty, and which would certainly produce unlimited power, would be a 30-mile tunnel through the eastern end of the Himalaya to short-circuit the long hairpin bend of the Tsangpo round Namcha Barwa, the 25,000-feet snow peak which stands sentinel over the Tsangpo gorge. As the Tsangpo flows past the northern flank of Namcha Barwa at an altitude of about 8000 feet and past the southern flank, 30 miles distant across the range, at an altitude of 4000 feet, this project is perfectly feasible.

However, this is a digression....

It is from the dry deltas of the Middle East, perhaps the first regions to be settled by man, that archaeologists have obtained evidence concerning ancient cultures dating back 6000 years. The Rosetta Stone, which gave the key to Egyptian writing, was dug up in the Nile delta. But the delta of the Indus, though known to contain relics of a civilization almost as ancient as anything in Egypt or Mesopotamia, has as yet hardly been touched. Nor is it likely that the last discoveries have been made in the Nile delta.

The civilizations of the Far Eastern tropical belt, which came long after, were not at first associated with deltas. Assam's ancient capitals were situated far up the Brahmaputra, those of Burma centred round the dry zone in the heart of the country, where stands modern Mandalay. In Siam the capital lay east of the delta, in Java early civilization was in the centre of the island, and in Cambodia near Tonle Sap on the western edge of the Mekong delta. All these civilizations are modern compared with those of the West. No city much more than a thousand years old is known, and even allowing for the destructive effect of the climate, it is certain that no great buildings dating back even a thousand years earlier ever existed. The peninsulas of South East Asia were colonized by already civilized peoples who came out of the heart of Asia and from India and China less than 2000 years ago. Before that they were occupied by wandering tribes with a Stone Age culture.

It is obvious that it took man much longer to subdue the overwhelming vegetation of the tropics than it did to learn how to raise food crops by irrigation in a semi-desert region. Three or four thousand years elapsed between the heyday of Middle-East culture and the rise of those Indonesian cultures. Nor does it appear that the latter learnt much from the former. The problems which the Chinese successfully overcame in the north-eastern part of China, in the valley of the Hwang Ho, were no doubt not very different from those of the West, and Chinese civilization, which later spread southwards to the Canton delta, developed during the 2000 or 3000 years prior to the rise of civilizations in South East Asia.

Of late years the agricultural wealth of tropical deltas has focused attention upon them. The deltas of South East Asia have all become sites for great seaports, generally situated at some distance from the sea on a barely navigable river connected with the delta, as Calcutta, Rangoon, Bangkok and Saigon. The reason is obvious. The rivers are navigable for hundreds of miles into the interior, and are of course the natural outlet to the sea. The land is flat, overland communica-

tions are easy Labour is plentiful and food is cheap, industrialism has everything in its favour, including often a wealth of essential mineral raw materials, like coal and iron, close at hand But to industrialize the tropical deltas, thereby reducing their potential agricultural area and at the same time increasing their population, is a very short sighted policy, and one calculated to raise grave problems

Coastal cities in future will lay themselves open to three-dimensional warfare and to combined operations on a big scale Inland cities, though open to aerial bombardment and para troops, are at least safe from sea borne artillery But safest of all will be mountain cities

XII

PLAINS

FROM what has been said about Earth features it will be clear that there are three primary surface features of the land crust; plains, mountains and rivers. The sequence is clear. The crust is pushed up above sea-level to form mountains, plains and plateaux. This land at once interrupts the gentle flow of currents in air and sea; the higher and wider the land, the greater the agitation produced; high mountains cause violent eddies and turbulence. Thus a much more dynamic factor than latitude for producing variety of climate is introduced. Clouds at once form owing to the cooling of saturated air in contact with cold land, and rain begins to fall. Rivers are born; and the wearing away of the land begins.

As a result of the work of rivers, and also of glaciers, valleys and deltas are formed. Secondary mountain ranges are also carved out of original ranges. The rivers form flood plains in their lower valleys, fill up troughs to form plains, and steadily push their deltas seaward, increasing the width of the coastal plain.

Of all land features, mountains and plains are the most obvious because the most conspicuous to the great majority of people. For it is on the plains that men dwell in the greatest numbers. About 3/4ths of the human race live on the plains, not necessarily at sea-level — the great plains of the Middle West, U.S.A., are several thousand feet above sea-level. But the plain of Europe, from the North Sea to the Urals, nowhere rises more than a few hundred feet above sea-level. Beyond the Urals it stretches on again unbroken to the shores of the Pacific.

About 1/3rd of the land surface is more than 3000 feet above sea-level, and this includes elevated plains which are

really plateaux, like Africa The remaining 2/3rds, however, is by no means all plains

But it is under the sea that really extensive plains occur The land plains including even the submerged coastal shelf are small compared with the vast submarine plains which lie at depths of 12,000 to 18,000 feet under the sea About 40 per cent of the ocean floor, that is 3/5ths of the lithosphere, lies between 2¼ and 3¼ miles below the surface Much of this floor appears to consist of endless plains, covered with a comparatively thin carpet of red clay, Globigerina ooze, or siliceous sand, or perhaps they may be compared with huge saucers, which contain the seas Hence it would seem that the greater part of the lithosphere is comparatively level, and that mountains are exceptional, although more than 1/3rd of the land surface is hilly or mountainous Nor must we overlook the fact that a considerable area of high land has been worn down to the level of plains by the work of rivers

The plains are the granaries of the modern world, as indeed they were of the ancient world, and hence are of the greatest importance to man By far the greater part of the world s agricultural produce, not food only, but fibre plants like flax and cotton, vegetable oil, seeds like rape, drugs and many other economic plants, not to mention timber, is produced on the plains Where they are not cultivated the plains are mostly covered with pasture and used for raising stock, or with forest

From the earliest times man has inhabited the plains in preference to the mountains, cultivated the land, improved communication, raised stock, carried on mining and built great cities All the great cities of the world are on the plains, close to food producing areas It is easier to cultivate the plains than the mountains, and easier to move about on them, the chief land communications of the continents, whether rail or road, lie across the great plains With the exception of coal and iron, however, the mineral wealth of the world lies mostly in the mountains Oil is found both on the plains and in the mountains

PLAINS

Ancient man must have been confined almost entirely to the plains, more particularly to the open grassland plains, where food and water could easily be obtained, food from the enormous herds of hoofed animals which roamed over the grassland plains during and after the great ice-age, and from fish caught in the lakes and rivers, as well as along the coast, and water almost anywhere He could have made much less progress in the tropics, where the plains were generally covered with jungle In fact the largest areas of tropical evergreen rain forest are associated with the plains of Brazil and of the Congo basin It was not until quite late in the history of man that he settled on the tropical plains and on the deltas of tropical rivers

There was always fierce competition for possession of the plains and an easy style of life The defeated were driven out, and either took refuge in the mountains or fled deeper into the jungle, or they were absorbed

All the most ancient civilizations centred on plains and deltas, and here the arts of agriculture, the domestication of animals, irrigation, and a more stable society were invented Assyria, Babylon, Egypt and further east, the Indus delta, the upper Ganges valley, the North China plain, tell the story of civilization The most powerful peoples were those with the largest food supply, the best system of irrigation, the most developed lines of communications, and the most highly organized populations For early civilization mountains did not exist No wonder people believed the Earth was flat!

But plains though they all look much alike except in so far as they are clothed with different types of vegetation, were not all formed in the same way The great plains of the land surface are mostly uplifted plains, though they have since been altered by further deposits from the mountains, and so show a hybrid origin The narrow coastal plains are also often regions of uplift, though they also are areas of deposition like deltas The flood plains of river valleys are also plains of deposition, as are alluvial fans Yet another type is the plain

which slopes gently away from a range of mountains, formed of material washed down and spread out along its foot Such plains can be seen in all stages of construction, beginning with a row of alluvial fans whose expanding bases presently join up, and very gradually flatten and spread, and ending with the finished plain, apparently level, which when closely examined has a perceptible though gradual slope Good examples may be seen at the foot of any range of mountains where there is a fairly heavy rainfall, with or without snow-fall at higher altitudes Siliguri on the plain of Bengal, the terminus of the Darjeeling railway, is 1000 feet above Calcutta, the slope being imperceptible The narrow plain on which the city of Tali in Yunnan is built, between the lake and the western range, looks fairly level, but the fact that water flows from one rice terrace to the next reveals the gentle slope.

Rivers are responsible for the building up of many platform like plains or terraces as well as for slowly wearing down mountains until their stumps only remain to remind us that these plains—peneplains—were once mountains Some of the most ancient mountain ranges in the world have been so planed down that had not their roots been recognized no one would have suspected that there had ever been any mountains there Glaciers too have been responsible for some plains And finally there are the small filled in basins which give rise to those plains entirely surrounded by mountains which so surprise and delight the eye of the traveller in the highlands The Red Basin of Szechwan is a familiar example Much smaller are the curious isolated plains of Hkamti Long in North Burma and of Imphal in Manipur State All three are silted up lake-basins, and were probably lakes during the glacial age — when the climate of the whole region between the Eastern Himalaya and Central China must have been very much wetter than it is now, and dotted with lakes, as Canada and Finland are to-day Some of these lakes still exist, notably in Yunnan, considerably shrunken, others have disappeared, or left only marshes

The lower valleys of great rivers like the Yangtze, Irrawaddy and Brahmaputra, as well as those which like the Yenesi or the Mississippi traverse vast plains, are the flood plains Assam consists mainly of the flood plain of the Brahmaputra and its tributaries, it is a triangular or funnel shaped plain interrupted near its mouth by outcrops of ancient hills, the Khasi Hills No doubt it was at one time an arm of the sea, then it became a swamp, and finally dry land The Brahmaputra, meandering over it, deposits fresh layers of silt each year

* The Ganges valley was a trough, a deep arm of the sea penetrating from the Bay of Bengal, which separated the Himalaya from peninsular India It was eventually filled up with gravel washed down from the Himalaya, and to day forms part of the great plains of India

Some of the greatest plains in the world are the alluvial plains which were uplifted ready made Such uplifted plains are familiar along coasts, where, however, they often form only a narrow strip between the sea and the mountains, as along the west coast of India at the foot of the Ghats, the east coast of South America, parts of the African coast and Southern Australia These coasts may at present actually be sinking Continental alluvial plains may occur far from the sea, for example, the great plains of the Middle West, in the United States of America, and the still greater Eurasian plain, which stretches across the entire continent from the Atlantic to the Pacific, with only a partial interruption at the Urals These plains, however, are of composite structure, since they consist of *two* ages of alluvia, that which was deposited when they were under the sea, and that which has been spread over them by rivers and glaciers since first they became dry land Their foundation is built up of thousands of feet of silt, overlaid by thousands of feet of debris The Assam Valley and the Ganges Valley are both being further overlaid to day with debris brought down from the Himalaya, as well as by annual layers of river silt

Europe and Australia are the only two continents in which

the area of plains exceeds the area covered by mountains Europe, in fact, is mainly a continental plain, and is surrounded by shallow seas, which, if uplifted a very few hundred feet, would almost double the plains area

The plains where so much of the world s food is raised are exposed to certain hazards especially to floods, and also in many parts of the world to drought It is chiefly the flood plains of big rivers like the Mississippi, Hwang Ho, Yangtze and Brahmaputra and no doubt many smaller ones such as the Damoda in Bengal which are subject to flood, and this may happen almost *every* year Droughts of greater or less intensity take place at fairly regular intervals in the South Western States of the U S A , in Southern Australia and Queensland, in North Western China and in parts of India

Many fertile plains have everything except water, and when irrigated yield abundant crops — Mesopotamia (Iraq), for example, which 3000 years ago was the granary of the Middle East When the irrigation canals were neglected, the country reverted to desert

In many parts of India large irrigation works have been installed, and in far Western China, the Red Basin of Szechwan is irrigated by an elaborate system of canals and dams The area of plains under irrigation in the modern world is very great and likely to increase But there is obviously a limit to the area of desert which can profitably be irrigated

In Canada and Russia man is up against a different problem There are wide plains in Northern Canada where crops could raised but tl e summers are too short to ripen the grain Bu: breeders therefore turned their attention to producing a up la hich would ripen in the short Canadian summer, and — when to admirably that wheat is now grown in Canada as Himalaya ao d/Crees Here again there is a limit, beyond wetter than it is never ripen, that limit has probably been Finland are to-day

Yunnan, considerab to which plains at the foot of the moun left only marshes valleys are exposed has all unwittingly

been greatly increased by man himself In his zeal to cultivate the Earth he abuses his power over Nature, never absolute, and Nature retaliates Those plains of India and China which possess a forest climate were no doubt cleared of forest 2000 or 3000 years ago It may be that these countries and even regions further afield are paying a heavy price for that reckless act, for some at least of the floods and droughts which periodically devastate whole provinces in China and, less frequently, India, must be attributed to the disappearance of forest, followed by a change of humidity, lowered water table, greater run-off, greater evaporation, silting of rivers and so on in ever-widening circles In our own day we have seen great changes take place in the Middle Western States of the U S.A where deforestation, deep ploughing and over-cropping have done irreparable harm to the land.

Yet cultivation of the Earth is necessary if man is to live and advance at all What then must be done to avoid the evil consequences of deforestation? The answer is to be found in the long term *provision for its replacement, in careful selection* of the area and avoidance of too rapid destruction, in irrigation of arid regions and river control — in short of large scale long-range working plans for the region The most severe damage far and wide is done when the mountains are denuded of forest That is *something which needs drastic action, because it is to* the mountains that men's eyes will now turn

The world's food supply is a problem which has suddenly assumed a vital importance There are two ways of increasing it (i) by bringing more land under cultivation, (ii) by making the same area of land *produce more and better crops, using* selected seed and adopting better methods of cultivation Ultimately it is the man on the land who is responsible

More land may be brought under cultivation by clearing more forest, by irrigation or by the introduction of cold-resistant or drought *resistant crops* It *is* doubtful whether much more land can be cleared for cultivation without doing serious damage in other directions, but more semi-desert or

and land will doubtless be irrigated Yet the end of the world's arable land may be in sight, at least it is not far off The available food supply could be made to go further by discouraging people from over-eating, that is, by rationing, but in a so called free country, that is a war time measure which is unlikely to survive the war for long

Nevertheless, it would be a mistake to think that because the world has not yet reached maximum production, it never will do so It would be possible to estimate just how much more land could be brought under cultivation, and what percentage increase on present production the improvements mentioned above might be expected to produce At present no figures are available for world food production — no *accurate* figures are available even for India, Burma or Siam, let alone China, amongst the largest agricultural areas in the world

But when all these calculations have been made there is still one unknown factor — population With religious dogmas and social customs urging half the world's population to have more and more children without a thought for the morrow, a point must some day be reached when world population outstrips world food supply A point *has* long since been reached when, in many parts of the world, local population has outstripped local food supply Then food has to be imported from surplus areas, but so long as it can be paid for, and transport is available, there will be no lack of willing sellers — at a price But surplus areas are not immutable

During the next decade there will probably be attempts at large scale industrialization in South East Asia and a great expansion of industrialization in America and Europe India and China, which between them contain nearly 1/3rd of the world's population, are neither of them surplus regions, though both of them include surplus areas Nevertheless, in order to assure a flow of vital raw materials, industrial leaders will probably be willing to export food, even at the cost of starving sections of their own populations, which may be nature's inscrutable way of adjusting population to food

supply. Even if they are not, it is highly unlikely that they will be able to *import* it without creating shortages elsewhere. The battle of the plains is the battle between a sane agriculture and industrialization.

In other words, agriculture comes first, particularly in India, China and the countries of tropical Asia, where more than 75 per cent of the population are peasants. Agriculture is dependent to an overwhelming degree on the plains, and the first duty of governments is to prevent recurring catastrophes by flood and to keep rivers open to navigation — that is to say, river control. The prevention of drought is another matter.

About 40 per cent of the total land surface of the Earth consists of plains, though some of this is desert; most deserts, however, are elevated regions. Generally speaking, the plains stretch away from the foot of the mountain ranges on one flank, and are associated with the lower sections of the great rivers which flow across them from those mountain ranges. Plains are often continuous with river valleys for hundreds of miles inland; or they may be mere coastal strips and deltas. Thus they are usually well watered, or at least capable of being irrigated. As we have seen, they are not necessarily at or even close to sea-level. Holland consists entirely of plains which are *at* sea-level; unless these were protected by dykes they would be inundated at high tide. In Russian Central Asia around the Sea of Aral are plains *below* sea-level. Tibet consists of a great plateau which is really a series of highly elevated plains; but plateaux are rarely if ever as level as true plains, though they too may have been beneath the sea — as Tibet formerly was, though at a much lower level.

For more than 6000 years civilized man has been living on the plains, cultivating them, building cities, enlarging his inheritance. For the last few hundred years only has he raised his eyes to the hills. The plains are becoming sour and exhausted. Meanwhile man's technique and knowledge have increased so much that he has begun to live in the mountains. One may well ask, will man turn away from the ruined and

ravished plains in disgust and seek peace in the solitudes of the mountains looking down from Olympian heights on the peoples of the plain below? The boldest of them may yet do so Under modern conditions the highland people, especially in the tropical zone, have a great advantage over the plainsmen

Colonization of the high plains and plateaux of Central Asia by pioneers is possible to a people of *courage* and imagination Just as the Americans colonized their own rugged West, so could they colonize ancient lands This much is certain Without colonization and a new pioneer spirit, Asia will remain hollow

MOUNTAINS

GEOLOGISTS formerly believed in a simple theory of mountain formation by shrinkage of the Earth's crust to fit a cooling core, which resulted in throwing the surface into wrinkles But as their researches probed deeper they found that mountain ranges were in fact not so simple, and not to be so simply accounted for

After the discovery of radio activity geophysicists maintained that the contraction theory was inadequate to account for mountain building, at least by itself In the words of Dr J H J Poole 'Before the radio active elements were discovered the main difficulty then was to explain how the Earth took such a long time to cool Since the discovery of these elements, however we are forced to make rather uncertain assumptions to explain how the Earth has ever cooled at all!'[1]

No theory of the Earth's crust, as regards its formation and cooling, at present put forward satisfies all scientific men Here we must be content to accept mountain ranges as a fact, without any attempt at explanation of how they came to be We may talk of them as crust wrinkles without suggesting more than that they look like crust wrinkles, and it is likely that contraction played some part in their formation Their structure, however, when laid bare by the discerning eye of the geologist, is far from simple

Whatever they looked like when they first became visible above the surface of the ocean, we see them now after many millions of years of weathering — the work of rain and snow, rivers, glaciers, wind, heat and cold But it is unlikely that they ever did look like the simple figures and diagrams we draw in order to explain their origin because uplift and sculpturing have kept pace with one another By the time crustal upheavals

[1] *Geographical Journal* November 1931

had reached the dignity of mountains they had already been wrought upon by surface forces for untold ages

Geologists believe that there have been periods in the Earth's history when mountain building was especially active, accompanied perhaps by volcanic activity At least two such periods are recognized The earlier period was so remote, that the mountains then uplifted have been planed down almost to sea level they have been worn down to their roots like the teeth of an old dog The later era of mountain building, to which most of the present mountain ranges of the world owe their existence, took place during the late Secondary and early Tertiary epoch The Tertiary epoch is reckoned to have begun not less than a hundred million years ago, with the Eocene period The Alps, the Himalayas, the Andes and Rockies, the Tibetan plateau and other great uplifts belong to this phase of mountain building, which may still be going on But there are certainly isolated mountains which belong to neither period and perhaps to no period Such isolated mountains are usually volcanoes — Vesuvius, Fujiyama and the curiously isolated extinct volcano of Popa in Burma may be mentioned At the same time one would expect volcanic outbursts to be associated with the crustal instability of a mountain building period, when the crust was readjusting itself more or less violently to a shrinking core Such volcanic outbursts are certainly associated with the formation of many archipelagos, peninsulas, and a general breaking up process on the fringes of the continents, such as took place in South East Asia

Of all features on the Earth s surface mountain ranges are the most conspicuous, though less familiar to millions than are the plains, they are infinitely more dramatic Few, indeed, can gaze upon snow ranges for the first time without feeling the heart beat faster, a feeling of awe in the presence of sublime grandeur Mountains are at once a challenge and a summons And yet it was not always so For thousands of years man looked upon mountains with awe, yes, but it was awe mixed with fear Mountains were the mysterious abode of the gods, of spirits, of

demons It was not merely dangerous, it was impious to violate their sanctity So of course it was dangerous too

The fact that the materials out of which a mountain range is built may differ widely is obvious to the least observant The scenery along a limestone range is very different from that along a granite range — sharp fretted ridges as against blunt towers and smooth cliffs Different again is a sandstone range, and to differences of structure may be added differences of vegetation Thus the mountain landscape tells us something of the underlying rock

One is apt to think that only within the last two centuries, and especially within the last century, since mountaineering became a sport, has equipment been equal to the task of reaching the high spots It is no doubt true that anything much above 18,000 feet was unattainable until the nineteenth century for lack of technical aid — and assuredly no one was so fool hardy as to attempt to *scale* summits before that Yet it is surprising what journeys *were* made, both by sea and land, 2000 years ago, with primitive means Fa Hsian with a considerable party crossed Central Asia, the Karakoram and Himalayan passes, in 400 B C The mountains bordering India may have been crossed long before that The spirit of man has ever been far in advance of his equipment The modern danger is that material equipment is catching up and forging ahead, spiritual equipment is lagging behind

Only about 1/25th of the land surface is raised one mile above sea level — 5280 feet, 1/30th is 6000 feet or more, half the entire surface lies 30,000 feet below sea-level! But 1/25th of 56 million square miles means over two million square miles of mountainous country — and a good deal of the remainder is at least hilly Hills rising only to 4000 feet, if much cut up by valleys and covered with thick forest, can be very impenetrable and very uninhabitable Then there is desert, much of which is below 5000 feet and excluded from the above estimate. Altogether the area of desirable habitable land is not so extensive as might appear

Of course the mountains of the world are far less explored than the plains, even where the plains are covered with jungle. The modern method is to view mountains from the air, map them by photography, and write them off as explored.

Mountains have a decisive effect on climate, being a powerful promoter of atmospheric circulation. They cool the air currents which blow against them to a much greater degree than they would be cooled at the same altitude if there were no land. Hence the heavy rainfall in many mountain areas as compared with the adjacent plains. During the south west monsoon which blows throughout the summer months, the Eastern Himalaya and the Burma-Assam ranges between India and China are smothered in cloud and invisible from the plains for weeks on end. The snow ranges of Western New Guinea are very rarely visible. As a result, at moderate elevations, where the climate is mild, they are covered with some of the thickest jungle in the world.

But mountains are not the cause of moist winds. They do not inject moisture into the air, nor, if it is not there, can they extract it. If dry winds blow across mountain ranges, they remain dry, and the mountains are without forest. Thus only dry winds blow over the mountains of Arabia and of North Africa, Baluchistan, Persia — in fact, over most of the mountains of the great desert belt of Africa-Asia.

The western slopes of the Andes, in Ecuador, Peru and Bolivia, the northern slopes of the Himalaya, and the Kuen Lun to the north of the Tibet plateau, are also comparatively dry. Still further north, however, the Tien Shan, though bordering the Central Asian desert, is forested on its cool northern flank.

Here note that Andes and Himalaya are rain screens, with one wet and one dry flank, such rain screens being indeed characteristic of mountainous regions. This is very noticeable along the Sino-Tibetan frontier, where the *apparent* trend of mountain ranges is north south, parallel to the upper courses of the four rivers, Irrawaddy, Salween, Mekong and Yangtze

In the Salween valley, in about lat 28° the climate changes abruptly from wet to dry within a few miles, the difference of rainfall being so considerable that whereas south of lat 28° evergreen jungle grows at the bottom of the valley, north of 28° 15′ there are no trees at all within 2000 feet of the river The contrast of climate, as reflected in the type of vegetation, is indeed astonishing, and is the more remarkable because the rain bearing wind comes from the west Yet all four valleys, or rather gorges, with the exception of the Irrawaddy which is the most westerly and wet throughout, become progressively drier from south to north, not as one would expect from west to east This indicates a rain screen stretching across the gorge country from north west to south east in about lat 28° It further corresponds with a transverse belt of high peaks situated on successive north south ranges

While on the subject of mountains attracting rain it will be convenient to refer to plateaux and secondary ranges Plateaux are uplifted plains, but their surfaces are usually far more irregular than plains They commonly occur between two parallel mountain ranges, unless we take the view that the plateau is traversed, as the plateau of Tibet appears to be traversed, by a series of parallel ridges

But old plateaux, especially in wet regions like South East Asia, do not always remain plateaux in appearance Their origin, as revealed by their underlying structure, may be that of a plateau, but outwardly they may appear as a jumble of mountains There are several plateaux bordering Tibet and Western China which the layman would never recognize as such because of the wear and tear they have undergone As a result a network of secondary ranges has been carved out, sundered by a network of deeply eroded valleys

A further complication has been introduced by the dual nature of the operation for some of the plateaux have been twice dissected, first by ice and secondly by water This is conspicuous on the plateau of Yunnan, in the north west corner of that province, and further west on the Irrawaddy

plateau of North Burma. The Shan plateau in Eastern Burma appears to be water-worn only. The Mexican, Bolivian, Persian and other dry plateaux, like the Tibet plateau (except in its south-eastern corner) are much less dissected and retain in some degree at least the external appearance of a plateau.

The Tibet plateau, the highest plateau in the world, is traversed from west to east by a number of lofty ranges, separating long, comparatively narrow, trough-like valleys.

Of course, whether a tract of country can be described as a plateau or not depends neither upon its external appearance nor upon its vegetation cover, which may be forest as on the Irrawaddy plateau, grassland as on the Afghan plateau, or nothing as on the Tibet plateau, but upon its foundations. That mountainous Yunnan is fundamentally a plateau is clearly shown by the long, level-topped mountain ranges, which indicate the former surface; the valleys, of course, have been produced, not by bending as a sheet of corrugated iron is bent, but by erosion. This is equally clear on the Irrawaddy plateau, north of Myitkyina.

Since mountains cause heavy precipitation, they necessarily nourish great rivers. Generally speaking, the greatest mountain ranges in the world are the sources of the greatest rivers in the world. The Mississippi, one of the world's greatest rivers, does not rise amongst particularly high mountains, neither does the Nile, which shows that there are other factors at work in determining at least the length of a river. But it would be true to say that the Himalayan mountains discharge more water to the Indian Ocean than the Rocky Mountains do to the Atlantic and Pacific Oceans combined.

I referred earlier to isolated mountains, most of which are of volcanic origin. From the point of view of the naturalist geographer, isolated mountains are of peculiar interest because they support an isolated flora and fauna, which may be a relic or may be modern, but which are most probably a mixture of the two. Nor is it always easy to determine which is which. The past, perhaps the long past history of the region, the

possible age of the flora or fauna and its geological horizon, the possible migration routes, the mechanism of evolution are all problems to which the naturalist seeks answers.

Isolated mountains like Kilimanjaro, Ruwenzori and Elgon, all extinct volcanoes, offer scope for research. But there are many isolated peaks included within mountainous areas, rising a few thousand feet above their neighbours, which are equally interesting. I have referred elsewhere to Dapha Bum and Saramati, the former a mountain in Assam, the latter on the Burma-Assam frontier.[1]

Mountains which rise above the snow line offer a whole new series of problems. The snow line, of course, varies very considerably even on the same mountain range, the amount of precipitation received being the most important factor. It also varies from year to year. One might reasonably expect it to be highest on the equator because of the high temperature throughout the year. Yet even in the heart of a great land mass like Africa it is actually lower on the equator than it is in, say, Central Tibet 35 degrees north of the equator. Ruwenzori, 16,734 feet high, for example, has a number of glaciers, and so has Kenya which is over 19,000 feet. The snow line is probably about 15,000 feet. In New Guinea it is even lower by reason of the tremendous precipitation which, falling always as snow along the crest of the main central range, keeps numerous small glaciers alive. In Western Tibet, the snow line is about 19,000 feet (Ruttledge). On the north face of the Eastern Himalaya it is between 17,000 and 18,000 feet, except in the extreme top corner of Assam where it is lower; on the southern face it is about 16,000 feet. The heavy rain comes during the summer, and it comes from the direction of the warm Indian Ocean and the plain of Bengal. Consequently the snow line is comparatively high, even on the windward face. By the time the wind has crossed the mountains it has dropped much of its moisture, and the snow line is raised on the northern face, and still further raised north of the Tsangpo valley.

[1] *Modern Exploration*, by F. Kingdon Ward (Cape, 1945).

In winter the north wind is comparatively dry, but what moisture it does contain is deposited on the northern slopes of the Himalaya, where the rock is colder than on the south face, protected as the latter is by vegetation and warmed to some extent by air rising from the plains.

North Burma has only one small group of snow peaks, rising to just over 19,000 feet; the snow line is about 17,000 feet. But between 14,000 and 16,000 feet hundreds of snow beds may be found persisting in sheltered gullies throughout the summer, though never increasing in size.

The level to which glaciers descend depends upon their size, steepness, and upon whether they face north or south. Although the snow line is as we have just seen low on the equator, most equatorial peaks are not very high; hence we do not find large glaciers — those of Ruwenzori scarcely descend below 14,000 feet. The equatorial Andes on the other hand are over 21,000 feet; but as they happen to be in an arid belt, the snow line is much higher than on Ruwenzori, and the glaciers do not descend to low levels. The glaciers of Ka Karpo Razi, in North Burma, descend to about 12,000 feet, possibly lower on the northern face. Namcha Barwa, at the eastern end of the main Himalayan range, is over 25,000 feet, and being in a very wet region, it naturally has several large glaciers which, in the Tsangpo gorge, descend to 9000 feet.

In high latitudes glaciers may descend to sea-level, the snow line itself, as in Great Britain, being only a very few thousand feet above sea-level.

Thus in high latitudes there is little scope for variety of vegetation — the climate near sea-level is such that only one type of forest can survive, namely conifer forest. At higher levels conifer forest is succeeded by birch and willow scrub, and that in turn by Alpine herbaceous vegetation.

On the equator also, although the type of vegetation changes with each few thousand feet of ascent, space is restricted.

It is in the warm temperate zone, on mountain ranges with a high snow line, that the greatest variety of vegetation, the

most clear-cut separation into belts, is encountered. In North Burma, between the valleys not more than 1000 feet above sea-level and the snow line at 17,000 feet, no less than seven distinct belts can be clearly defined, and several of these can be further subdivided. The naturalist is sure of a wide field of work in any mountainous region, particularly on the world's great ranges; and so also the plant-hunter, seeking new plants for old gardens. Fresh air, incomparable scenery, a tonic climate even when rainy (so long as one is high enough), and solitude are added attractions to be had in the mountains, rare or unobtainable on the plains.

Mountains share with deserts the distinction of being the chief stumbling blocks to overland movement. Throughout the ages they have kept races apart. Glancing at a physical map of the world, one begins to perceive some of the physical barriers against human migrations and the causes of isolation during the historic period and earlier, especially in Europe and Asia, where the great mountain ranges run transversely. The outstanding geographical feature of Asia is the wall of mountains which, striking out from the Pamir Plateau and early bifurcating north-east and south-east, reaches the one branch to beyond Lake Baikal, the other branch to the plateau of South-West China. The northern arm forced intercourse between Asia and Europe or Asia and India to follow a route north of the Tien Shan. The latter kept the civilizations of India and China apart. Indeed, all the Mongolian civilizations in tropical Asia, in Burma, in Siam, in Cambodia and Annam developed in comparative isolation because they were protected on three sides by mountains.

Despite mountains, deserts and seas the torch of civilization was carried across Europe and Asia to light the fires of progress. But the fires, though they continued to burn, even to illuminate the surrounding darkness, did not, could not spread. Cultures developed widely apart, ever diverging. It was the transverse mountain system, stretching from the Atlantic to the Black Sea, which more than anything else separated the civilized

peoples from the barbarians. This formidable barrier prevented the movement of cultured peoples overland into the continent of Europe and directed them westwards round the Mediterranean coasts from Asia Minor to the Iberian Peninsula. Africa remained the dark continent for another 300 years mainly because of the wall of mountains which guard the interior plateau. Reinforced along its northern shore by deserts, it was doubly protected. According to Haddon the only parts of Africa where movement of peoples was comparatively easy were (i) southwards down the east coast, (ii) westwards along the Mediterranean coast, north of the desert tract, (iii) westwards from the regions south of Khartoum, between the deserts to the north and the forests of the equatorial region to the south. (Haddon: *Races of Man.*)

Thus in Africa once the plateau which occupies most of the continent is attained, there is little opposition from mountains, but a great deal from desert and jungle.

Not till man had built ships which could follow the coast of Africa out into the open seas was progress made. The first ocean-going vessels might cross the Atlantic, and even sail round the world before they could navigate so treacherous a waterway as an African river with its bars and shoals and its numerous rapids, not to mention its savage tribes.

In America, on the other hand, the great ranges are meridional instead of transverse, and for long prevented contacts between east and west, diverting migrations southwards along the Atlantic and Pacific seaboards.

It would be easy to multiply examples, but enough has been said to draw attention to the importance of mountains as barriers; though this must not blind us to the fact that they may also act as guides to migrating populations moving along their base, as in Eastern India, where man has followed the base of the Himalaya up into the Assam Valley, and in Central Asia where he has followed the line of oases at the foot of the Kuen Lun.

What of the future? Mountainous regions were certainly

among the last to be occupied by man. To-day, the mountain population of the world is not negligible. On the basis of two persons per square mile, which is probably the lowest average density for any extensive area which is inhabited at all, it would amount to some five million people. But this figure is obviously far too low; the population of Tibet alone is estimated at about five million, most of which is concentrated in the mountainous south-eastern quadrant. Western Yunnan and Szechwan have a population running into several millions and at least half of Switzerland's four million inhabitants live in the mountains. In fact the mountain population of the world to-day can hardly be less than 25 million persons.

There can be little doubt that this population will tend to increase in the future. There are large towns in the Andes, in Mexico, in Tibet, China, the Himalaya, and even in Switzerland which are quite definitely in the mountains and many thousands of feet above sea-level. Mexico city is over 7000 feet; Quito over 9000 feet; Lhasa over 12,000 feet; Gyantse over 13,000 feet; and Litang over 14,000 feet. There is no difficulty in building cities, or for that matter in installing machinery in the mountains — it is mainly a question of expense. Water and power are there to hand. Good sites for settlement are abundant — small saucer-like plains, shallow bowls. Both Simla and Darjeeling, however, are built on the crests of ridges, the former 7000, the latter 6000 feet above sea-level. But there cannot be the same immense food production in the mountains that there is on the plains, although crops might be more varied. The present food supply however is no indication of what could be done, and there is abundant meat, fish, milk and butter to be had.

There is perhaps not much future for the extremely wet monsoon mountains, either in tropical Asia or anywhere else. North Burma and Assam, the southern slopes of the Eastern Himalayas, Ruwenzori, the western slopes of the Andes, and similar regions are not likely to attract many men; and the tendency of some of the tribes in Eastern India to leave their wet hills and mingle with the peoples of the plains is significant. Compara-

tively dry plateaux which can be irrigated, like the plateaux of eastern Tibet or the well watered but not rain sodden Shan plateau, are likely to attract men during the next century

Above all there is the matter of security A considerable area of the world and an enormous number of persons have during the last six years been bombarded from the sky It is much easier to bomb the plains than the mountains — and much more effective Apart from any other consideration it is easier to build shelter caves and tunnels in the mountains than on the plains, and if civilization is to be driven underground on the plains, it will perhaps prefer to survive beneath the sky in the hills Hitherto man has possessed neither the knowledge, the equipment, nor the technique to occupy the mountains on a large scale To day he possesses all three Like Kotik, the white seal, man will probably seek a more ordered and less bloody life in the mountains in a large way in the future It is a possibility geographers cannot afford to ignore

Furthermore there is a marked tendency for modern states to arise in mountainous regions — 70 per cent of the area of Japan is mountainous Switzerland and Scandinavia are both up to-date in technical equipment and their standard of living compares well with that of Britain Nepal though a backward state is advancing Afghanistan, Iran and Turkey all show signs of renaissance Peninsular India is hilly

From what has been said in this chapter, it will be apparent that mountains have profoundly influenced man, baulked him more than a little, but also protected him They do not, at least during the last 6000 8000 years, appear to have frustrated him completely in every age a chosen few have always crossed even the most formidable range In Asia, the most mountainous of all the continents, deserts and mountain ranges insured the survival of three great centres of ancient culture — the Middle East, North West India and Eastern China — permitting them to develop in isolation Nevertheless there were far more contacts between them than is generally supposed, even if the overland trade which was carried on left little permanent mark

XIV

LAKES

LAKE is a word which covers such a variety of earth structures that many lakes have nothing in common except that they contain water — otherwise they would not be lakes, though they might be near-lakes, as swamps, bogs, marshes and even plains, denoting stages in the life-history of lakes. Thus little can be said about lakes in general.

Together with rivers, lakes form part of the hydrosphere, that part of it which is land-based and usually — not always — fresh water.

At first sight it may seem startling, or at least far-fetched, to include all land-based water in the hydrosphere; but a little reflection will show that the idea is quite logical.

The hydrosphere, or ocean, rests as we know on the crust, and the 'land' after all is only crust which by some means has been raised up above the average level. Again all land-based water is ultimately derived from the sea and all — or most of it — returns thence. There are fresh water springs in the ocean floor, as well as on land. If one looks at a map of Finland or Lapland or Northern Canada where the relative proportion of water to land is about 1 : 3 this interweaving of hydrosphere and lithosphere becomes obvious; here the land surface is little more than a network with the meshes filled with water. It is only in the desert interior of a continent where water is rare and isolated that its oneness with the hydrosphere seems strained. Even water within the crust, meteoric water flowing beneath the surface and invisible, is part of the hydrosphere. Just as the clouds in the air, glaciers and ice-bergs are part of the hydrosphere, so also is the water in the lithosphere. We may note therefore that at any given time an immense volume of water which belongs to the ocean is actually on loan, circulating within the other two shells.

Finally an enormous but unknown volume of water is temporarily 'fixed' by living matter, which, consisting on the average of about 85 per cent water, is released on death. But this can hardly be said to be part of the hydrosphere though it was thence derived.

Lakes are usually associated with mountains, and most of the mountain ranges of the world with the curious exception of the Himalaya are generously sprinkled with lakes. Other mountain ranges conspicuously lacking in lakes are the Carpathians, the Caucasus, and the mountains of South-East Asia. Looking further afield however we find that though lakes are highly characteristic of mountainous regions — it will be enough to mention the European Alps, Scandinavia, the mountains of Western China, the New Zealand Alps, the plateaux of Iran, Turkestan and Tibet, the Andes, Sierra Nevada and Rockies — yet some of the greatest concentrations of lakes in the world are on the plains, as for example in Northern Canada, the North Eastern United States of America, Finland, the North German Plain and European Russia. The mountains then do not have it all their own way. It will be noticed however that these lake lands lie well within the area which was covered by the ice cap during the Pleistocene glaciation, and, since the mountain ranges known to be pitted with lakes are also glaciated even to-day, one may safely infer some connection between glaciers and lakes in both regions. It can hardly be a mere coincidence. Further we may note — though the evidence is of negative value — that those European mountains which escaped glaciation, such as the Pyrenees, have no lakes worth mentioning. Practically all existing lakes within the northern glaciated region, such as those of Canada, the great lakes of the United States of America, and of Russia were much larger during Pleistocene times. They have dwindled as the glaciers have shrunk. In hot desert regions lakes are exceptional, sometimes even illusory, so far as their containing water is concerned, for instance Lake Eyre in South Australia. Lake Eyre however probably contains some water at intervals for the most part

and in most years Lake Eyre (north) is a salt-encrusted plain.

On the other hand who would expect to find so many lakes in Algeria and Tunis! There is no evidence for the glaciation of the Atlas mountains, which in any case are some distance away.

Even in hot dry regions which are not deserts lakes are generally rare. There is not a single lake in the whole of peninsular India and even if there ever were any in connection with the Perm-Carboniferous glaciation of that ancient land, they have long since disappeared.

On the other hand there are many small lakes as well as glaciers on Ruwenzori in equatorial Africa (Humphreys). Even the absence of lakes in the Himalaya — a heavily glaciated region — is more apparent than real, for there are plenty of lakes on the northern though not on the southern slope where, owing to the heavy precipitation, they have perhaps been drained, or silted up. Lakes as lakes are much more at the mercy of events in the surrounding regions than are most Earth forms. Plains and mountains and rivers can be pushed around, but it is difficult to do away with them altogether. They can survive a good deal of rough treatment. But lakes are delicate. They can be drained, dried up, or filled up and so disappear comparatively rapidly. One infers that most existing lakes are not very ancient. As a gauge by which to measure alterations of climate, or a succession of wet and dry periods, they are invaluable to the scientist, since even after their complete disappearance they leave a record of their history which it is often possible to interpret.

The plains of Hkamti Long in North Burma and of Manipur in Assam were certainly lakes during the Pleistocene ice-age, and there are probably many such ancient lake beds on the plateau of Yunnan. The lakes of Central Asia and of Tibet have been gradually drying up as the glaciers which feed them shrink. Lop Nor in Turkistan has not merely shrunk; it has changed its position within historical times. Many of the East African lakes have shrunk considerably since the glacial age

during which equatorial Africa enjoyed pluvial and inter pluvial periods corresponding with glacial and inter glacial periods in higher altitudes (Leakey)

In prehistoric times lakes had a peculiar importance which they no longer have — they provided desirable residential sites and hence were centres of early civilization The Swiss lake dwellings of 3000 4000 B C are an example Nowadays lake shores as residential areas have nothing particular to offer which is not possessed in equal or even greater degree by many other places Lakes it is true figure prominently along certain trans continental railways but that is mainly because they lie along the chosen route and cannot well be avoided Occasionally the route may be selected because of the presence of lakes as the Cape to Cairo route where the lakes mark the direction of a great rift or valley but more often they have no fundamental place in the scheme Rather do they interrupt lines of com munication and necessitate a diversion as the Trans Siberian Railway *is carried round the southern shores of Lake Baikal* which stretches across its alignment Or freight is transhipped and ferried across an inconvenient lake from one railway ter minus to another which means increased labour costs and loss of time The huge Caspian Sea is a good example On the other hand railways have deliberately tapped the great lake regions of the world even in the heart of a continent notably the great lakes of North America such regions offering fresh sources of wealth and power in an industrial world

Taking a broad view however lakes do not rank very high amongst Earth features and it will not be necessary to say much about them The most important part in a geographical sense played by them is the same as that played by the ocean namely as climatic moderators Water always tends to soften the harsh ness of a continental climate to keep the air cooler in summer and warmer in winter Lakes in fact bring the influence of the sea on a small scale even into the heart of a continent though it is doubtful whether the numerous lakes of Western Tibet have any appreciable effect on that austere climate

Lakes may be fresh or salt, the latter confined to the desert regions of the world. They produce little wealth, fish and salt being the chief products; their most valuable raw material is often the fresh water itself. Yet most reservoirs for supplying water to towns are artificial, because lakes do not often occur near great cities. Cities are built on the plains, whereas lakes occur more frequently away from the plains. Nowadays however more and more new cities are being built on lake sides, especially in the United States, and in Russia on the shores of the Caspian Sea, much the largest lake in the world; but usually for some special reason, such as the presence of oil. In the course of the next century we may see more cities founded on lake shores, in Central Africa, in Canada, even in Tibet. Countries well provided with fresh water lakes may lead the world in aviation — or offer opportunities to some outside Power.

It must be remembered however that an industrial city needs not only water, but water power, and unless the lake can supply that it may be cheaper to build the city elsewhere and construct reservoirs and dams. Niagara is rather exceptional, and Victoria Falls on the Zambesi has nothing to do with the African lakes.

Water and water-power are not the only requirements of a modern industrial city, and the mere presence of a lake, however pleasant and indeed advantageous, cannot outweigh such considerations as access to coal, oil or iron, or to a navigable river and the open sea. There is however a special use for lakes in the future. I said above that in prehistoric times they had a peculiar significance which no longer belongs to them. Tomorrow they may have a significance they have never had before — as bases for flying boats. The African lakes and the great lakes of North America are being used to-day. If flying boats could take off at 15,000 feet, as in time they will, it would be possible to fly across Central Asia, hopping from lake to lake. At present perhaps no one has any incentive to fly across Central Asia; but that is not likely to be true for long.

If the hydrosphere were perfect, that is if there were no land,

there would of course be no lakes, only the great ocean basins in the Earth's crust We know little about the origin of these, though most geologists believe that they have been there for a very long time, if not always But while there may be some doubt as to how the great basins containing the oceans were formed in the crust, there is no mystery about the small lake basins in the land, although they originated in more ways than one. We find crater lakes, occupying the crater of an extinct volcano, valley lakes formed on the course of a river by a landslide blocking the lower end of an alpine valley, and lakes occupying hollows scooped out by ice Most existing glacier lakes are quite small, but there is strong evidence to suggest that the great American lakes were due to ice action, although the problem of their origin has never been completely solved In most mountain ranges, especially where glaciers still exist, small rock basin lakes are abundant They tend to disappear after the glaciers which ploughed or ground out their basins have retreated a certain distance, not because they dry up but because they silt up

Of alpine lakes, the Geneva lake is the best known, those of the English Lake District and of the New Zealand Alps scarcely less so

In the great mountain ranges of Tibet and of Western China, there are hundreds of small rock basin lakelets which add to the entrancing beauty of the scene, not least owing to their marvellous colours, as jade green, malachite green, or even emerald It is rather curious that there should be far more of these jewel like lakes among the lofty limestone peaks of Chinese Tibet than in the Himalaya themselves, at least in the better known parts such as Sikkim But the magnesian limestone of North West Yunnan is not readily soluble, and the rain fall being lighter than it is in Sikkim and the rock more porous, it is possible that the Chinese glacier lakes have been less silted up There may also have been a marked time-lag in the retreat of the Chinese glaciers, as compared with those of Sikkim, although the snow line is actually higher in Western China

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Whatever the reason, mountain lakes are rare in the Eastern Himalaya from Nepal, through Sikkim and Bhutan to the hairpin bend of the Tsangpo, while they are very numerous in the limestone ranges above Muli and other mountainous areas of North-West Yunnan and South-West Szechwan They are also uncommon in the little explored glaciated mountains which form the frontiers of North Eastern Assam, Northern Burma and South Eastern Tibet, although silted-up lake basins now converted into excellent pastures do occur There is a typical one just north of the Tse La, at the sources of the Irrawaddy, at an altitude of 12,000 feet

The innumerable lakes of Canada, Scandinavia, Finland, New Zealand and perhaps also of Tibet are due to glacier action

However there are other lake systems in the world which owe their origin to what geologists call diastrophism, that is to say a definite movement of the Earth's crust, either folding of the strata which are bent so as to form a sort of basin, or faulting, whereby a long narrow block of crust sinks, forming a gorge-like rift, with here and there a natural bulkhead to hold up the water The long narrow lakes of East Africa were formed in this way So also was the Dead Sea In the distant past, such earth movements have taken place on a continental scale, forming either immense basins or cracks (rifts) thousands of miles long

The Tibetan lakes, of which there are several hundred, have been shrinking for a very long time, they were formerly far more extensive But the Tibet plateau is 15 000-16,000 feet above sea level, while the Caspian Sea, which is also shrinking, is below the level of the Mediterranean

The Tibetan lakes are by no means the only ones which show unmistakable signs of drying up Those of Central Asia, of South Australia, of the Great Salt Lake region in the far west of the U S A and of Bolivia are also drying up, not to mention Lake Chad Even so there is no good evidence that the Earth as a whole is drying up On the contrary, almost everywhere the glaciers are advancing — the recent retrocession in the

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Himalaya and elsewhere is a mere temporary phase To the question — Is the Earth drying up? — Gregory replied with a decided 'no' [1]

The total area of the lakes of the world, fresh and salt, probably exceeds three-quarters of a million square miles Turned into arable or pasture land it sounds a lot — nearly 500 million acres Nevertheless it is a comparatively small proportion of the total land surface less than 01 per cent Deserts and semi deserts take up sixteen times as much of the surface, which seems to suggest either a serious deficit of land based water or a very unequal distribution of it But the latter area of unproductive land includes some of the lakes Land based water, however, includes rivers as well as lakes, and these take up a vastly greater area Man does not grudge the area taken up by rivers which over a large part of the world are in fact sadly deficient.

But lakes as I have tried to show, play but a minor part in the economy of the world at present They are rather in the nature of curiosities among land features though they have trivial uses That is the utilitarian view A country without lakes, or with only minor lakes, is not necessarily handicapped in the industrial struggle, as a country without navigable rivers is handicapped For lakes are only large reservoirs, and reservoirs, indeed lakes can be and are man made

But it is well not to lose sight of the aesthetic value of earth forms, amongst which lakes, particularly mountain lakes take a high place To the naturalist also they are of abiding interest, and many scientific expeditions in the future are likely to be directed towards the intensive study of lakes We know almost nothing of the hundreds of alpine lakes situated between 12,000 and 17,000 feet in the mountains of Western China, or of the Tibetan lakes, or of the Andine lakes Most alpine lakes are small but some of the Andine and Tibetan lakes, though many thousand feet above sea level, are of considerable size Lake Titicaca in the Andes, 12 f 11 feet above sea level covers 2000

[1] *Geograph cal Journal*

square miles and has a maximum depth of 892 feet. Nam Tso or Tengri Nor, the great lake north-west of Lhasa, covers about 400 square miles and is 15,200 feet above sea-level; while the Dead Sea, which is 1292 feet *below* sea-level, covers 340 square miles.

Similarly the Caspian Sea, which has an area of about 170,000 square miles, is 85 feet below sea-level. It is the largest remnant of the great Mesozoic Sea called Tethys which stretched north-eastwards from the Mediterranean and covered much of Turkistan and Tibet, including the Sea of Aral, Lakes Issikul and Balkash.

ISLANDS

To many of us brought up in the tradition of *Treasure Island*, *The Coral Island* and other good stories islands at least tropical islands still reek of romance However let us take a more realistic view of them here Since the Pacific war even the Blue Lagoon School have taken a more objective view of lotus eating

To the modern geographer an island is something more than the school geography book s formal definition as a piece of land entirely surrounded by water The geographer wants to know what part islands as opposed to continental land masses have played and will play in the world Perhaps they do not play so important a part to-day as they have done in the distant past — but then many of them were not always the same islands in the distant past perhaps not islands at all Possibly they play an even more important part Who looking at Great Britain at Malta — even at Japan — dare say that islands have ever played so dramatic a part in the world as they are playing to-day? But it is from the point of view of their relationship with the mainlands that the geographer looks at them most keenly, and the historical importance of the warlike islands to-day is not disproportionate to the historical importance of the adjacent mainlands

The islands of the world are usually found to be in groups or clusters — archipelagos — but sometimes are completely isolated Since there is three times as much sea as land there is plenty of room for small islands, but in fact vast areas of ocean are unbroken by even the smallest island A study of the world map will show that the great majority of islands — disregarding for a moment the Pacific coral islands — are situated close to the continental lands and not infrequently are arranged in arcs along their coasts It has already been pointed out that the

oceanic basins are of great depth and have perhaps been where they are now since the beginning of the world If the Earth's crust buckles only within small limits of a thousand feet or so, up or down, it is easy to understand that islands are more likely to be formed along the continental coasts than in the oceanic basins, especially as we know that a shallow sea already spreads over much of the land (continental shelf) and can just as easily retreat, in places leaving islands of higher land But of course the problems involved are not so simple as that Land was up raised 29,000 feet to form Mount Everest — so why should not land be upraised from a sea bed 29 000 feet deep? Hawaii was perhaps uplifted 30,000 feet These are problems for the geologist and geophysicist rather than for the geographer, who takes the world as it is — and was — and may be, but it is as well to appreciate the difficulty It is enough for the geographer at present to recognize that there are two kinds of islands — continental islands and oceanic islands To these may be added a third class, coral islands, which owe their existence to the activities of the coral polyp Continental islands are surrounded by a comparatively shallow sea and have within geologically recent times been part of the mainland Oceanic islands, on the other hand, rise from great depths and have always, so far as is known, been islands or at any rate for a very long time

Australia is a very large oceanic island, or a small continent, whichever we like to call it New Zealand, another oceanic island, is certainly an island but hardly a continent while Hawaii has no pretensions to being a continent at all There is no reason why a small piece of crust like New Zealand should not be fashioned into land as well as a large piece like Asia — however it was done Perhaps it would have been more logical to call such deep sea islands continental, and find another name for coastal islands But the terms are now well understood

An archipelago, at least when near the coast, as most archipelagos are, always implies crust movements, the islands represent the higher elevations of a land which has sunk beneath a shallow sea, or the tops of mountains emerging If

there were to be an elevation of the sea floor between Malaya and New Guinea of no more than 600 feet, most of the area would become continuous land and Sumatra, Java, Borneo, Celebes and other islands would cease to be islands There are numbers of these sunken coast lands round the continents represented now only by chains or clusters of islands, the East and West Indies and the islands off the north coast of Canada, are examples On a smaller scale are the British Isles formerly joined to France and Belgium, the Mergui Archipelago off the Burma Siam coast and the Aegean islands between Greece and Asia Minor

There does not, however, seem to be any known region which is the reverse of the above that is to say, recently elevated land consisting of highland areas which have long been above sea level joined together by lowland which has only recently been under the sea Such regions may exist but would obviously be difficult to recognize Exceptions are delta areas, like the mouth of the Yangtze and coastal strips like the west coast of Siam Both these areas are recently submerged coast, whose peaks stood out of the shallow sea as islands

That all these archipelagos were once united with the nearest mainland is proved by several lines of argument, and particularly by the likeness of the plants and animals in the islands to those of the mainland, not resemblance merely, but identity

Oceanic islands have a fauna and flora of their own, unrelated to the fauna and flora of any mainland — or at least not closely related to it Endemic species — that is species peculiar to the island, and found nowhere else — are usually numerous Now endemics originate as a result of isolation Endemic animals and plants sometimes occur on mountain peaks rising in the midst of plains or on the summits of mountains which rise far above the general altitude of the surrounding mountains Of course, the fauna and flora of a high mountain will naturally be different from that of the surrounding lowlands owing to climatic differences But they ought not to differ from

that of neighbouring mountains, if they do, there must be some reason, and the reason is often the same as that invoked to account for endemism on oceanic islands, namely isolation The lonely mountain top in the heart of a continent is a floristic and faunistic 'island

It is generally possible to account for the isolation of an inland mountain, if not for an oceanic island But exactly why isolation should result in the birth of new species, animal or vegetable, is not so clear How Nature or Natural Selection or any other continuous and cumulative process actually works is by no means obvious, but work it does We observe the results, the method by which they are reached still eludes us

We may note that nearness to the mainland is not necessarily proof of an island's continental origin Whether it is to be regarded as continental or oceanic in origin depends on the depth of sea separating it from the nearest mainland and of course on comparisons with the mainland Depth of sea between islands will also indicate how recently the two islands were joined together — if they ever were If the island has always been an island, and particularly if it is as far from the nearest mainland as New Zealand is from Australia (1200 miles), or Mauritius from East Africa (1500 miles, over 500 miles from Madagascar), or Galapagos from Ecuador (600 miles), or Hawaii from anywhere, it will not fail to show a high degree of endemism Numerous endemic species and genera of both animals and plants occur in the islands named The entire fauna and flora depart widely from those of the nearest mainland This is due entirely to long and continuous isolation, and has nothing to do with the surrounding ocean except in so far as the great depth of the ocean is proof of the island s long continued existence That the sea as sea really has nothing to do with it is proved by the existence of 'biological islands' in continental lands referred to above Thus, as pointed out by Cotton the several isolated high mountains of equatorial Africa have each their own species of tree lobelia, differing from those on neighbouring mountains Explorers might well

pay closer attention to the natural history of mountain peaks, where close investigation would always yield interesting results

In the history of evolution oceanic islands are sanctuary for the hunted — for those of the hunted that can reach them But how few can! No mammal except a bat, ever succeeded in reaching New Zealand by itself, until man came But for man, though islands began as sanctuary, they too often ended as cemeteries This was of course because later and more powerful tribes no less than earlier ones, could also reach them, and reach them in force Once man had conquered the sea, islands ceased to be sanctuary for man There was no permanent security even in the midst of the greatest ocean, there is even less to-day, now that man has conquered the air Thus the Tasmanians were wiped out and many of the South Sea tribes are likely to be Other races more fortunate, are absorbed into the conquering tribe How many island peoples have been exterminated in the past it is of course impossible to say No doubt many

Nor have animals fared much better since the arrival of man So secure were islands like New Zealand and Mauritius for millions of years that birds ceased to fly, and lived on the ground They, or some of them, such as the dodo in Mauritius, quickly became extinct when man appeared bringing with him mammals, from which flightless birds were unable to escape, and guns

Thus the geographer recognizes two distinct types of island, those which in geologically recent times formed part of the mainland, separated from it by shallow narrow seas, less than a hundred fathoms deep, containing animals and plants similar to those of the mainland — and people too, and oceanic islands separated from the nearest lands by broad seas a thousand fathoms or more deep, which have not formed part of the mainland within recent geological time — not, that is to say, for millions of years Possibly they have never been part of the mainland Possibly they were heaved up from the floor of the ocean independently and represent some of the oldest visible

bits of the Earth's crust. But the distinction seems to be one of degree. Those who are interested in the subject, particularly in the distribution of animals and plants, and the evolution of life, should read that naturalist's classic, *Island Life*, by Alfred Russell Wallace.

Finally there are the Pacific islands, the atolls and coral islands which have been so much in the news of late. These fall into a class by themselves. I do not propose to say much about them beyond remarking that they are made up of the external skeletons of marine creatures which have been building them up slowly for millions of years on top of submarine volcanoes and other mountains in shallow water where the ocean floor appears to have been steadily sinking. Coral islands, however, are a study in themselves and the reader is referred to Darwin's *Voyage of the Beagle* and to the classic work of Stanley Gardiner for details.

Of course, islands which have once been part of the mainland may, in time — geological time — again be united with it. Sicily might be reunited to Italy, Sardinia to Corsica and both to Italy, Tasmania to Victoria, and so forth. That seems no more improbable than that islands which, like peninsular India, have been united to the mainland should be divorced from it again. It would need a subsidence of less than 250 feet to convert Bengal and the whole of the Ganges valley into a shallow sea, making peninsular India all but an island once more. (It was an island down to mid-Tertiary times, some 30 or 40 million years ago.)

From what was said about desert coasts it will not readily be assumed that islands in virtue of their proximity to the sea must enjoy a wet climate. Some do, not because they are pieces of land entirely surrounded by water, but because they lie in the track of rain-bearing winds. The island of Perim in the Red Sea is a desert, and Socotra, 200 miles from the coast of Africa, is little better. But Trinidad in the same latitude and about the same size, off the coast of Venezuela, is an extremely fertile island with a lavish vegetation. If an island, and parti-

cularly a mountainous island, does lie in the track of moist winds — and these, as we know, depend upon currents set up in the two fluid shells by the unequal heating and cooling of land and water — it is likely to have a very damp climate, with not only plenty of rain but also plenty of mist or cloud. The island itself will not, unless very big, seriously influence the main air currents except to force them to part with some of their moisture. Thus Falkland's Islands in the South Atlantic and Newfoundland in the North Atlantic are cold and damp with abundant rain at all seasons; and so are the adjacent coasts. Coastal islands, in fact, generally share the climate of the adjacent mainland, modified on its windward side. New Zealand's South Island and the southern islands of Japan enjoy so damp a climate that parts of them are — or were — covered with forest almost tropical in its luxuriance, the one 45 degrees south, the other 35 degrees north of the equator. Continental islands like Australia and Greenland, of course, behave like continents; the one is largely hot, the other largely cold desert: but the fact of their being islands has nothing to do with this. Still, even quite small tropical islands such as Ceylon, or Java, or Timor, as well as large islands like Madagascar, have wet and dry zones; one end of the island or one coast may be much wetter than the other and may get its rain at a different season, as in Ceylon. The west coast of Great Britain is milder than the east coast, and the north-west coast far wetter than the south-east.

Generally speaking, however, 'desert islands' do not exist — though they may be deserted — or uninhabited. The Red Sea and Persian Gulf islands are desert because they ha[illegible] to lie within the great desert belt of Asia and North Afr[illegible]

As stepping-stones from one continent to an[illegible] have a special interest. The Aleutian Islands [illegible] example, and appear to have afforded a route [illegible] Sea [illegible] stepped from Asia to America — though he pro[illegible], is [illegible] by boat from island to island. The Dutch East In[illegible] a route from Malaya to Australia, also probab[illegible]oat;

though it is possible that at the remote periods when these migrations took place these bridges were more complete than they are to day Of these migrations we know nothing except that they must have taken place All the Amerindian tribes as well as the Esquimo are of Mongolian origin The Australian tribes, in spite of living in the Stone Age, 4000 years after the Stone Age has passed in Europe, are of Caucasian stock, the same stock that gave origin to the Western European peoples None of them appear to have dropped any relics of their trek along the route But such relics may some day be turned up in the islands The most desirable would be skulls of those who fell by the way In their endeavour to escape from their pursuers, or simply as they were moved on, or in a spirit of adventure, tribes settled in the remotest tropical islands, far indeed from the madding crowd And there their culture froze, so that the peoples of the mainland soon surpassed them in the arts and, adventuring in their turn, exterminated the earliest islanders, or drove them still further afield Sometimes the relics of a former civilization have been left behind, like the stone images on Easter Island But these are modern compared with the first migrations

With the coming of flight, it was thought by many people that Great Britain would cease to be an island But that fear proved to be illusory in 1941 The new attack was met by a new defence, and the narrow sea was still uncrossed And so despite the ever increasing range and staying power of aircraft, islands elsewhere continue to be islands — pieces of land entirely surrounded by water — and, it might be added, entirely enveloped by air

It is possible that with the improvement in stratosphere flying, many small islands, now useful as perches for aircraft on trans ocean flights, may lose their importance and even sink back into obscurity But it seems likely that the control of the Pacific will, for a long time to come depend as much upon certain key islands as upon the mainland Strategically oceanic islands have become more important than continental islands

A word may be said about island arcs such as those of the West Indies, East Indies, Aleutians and Kuriles. These are really mountain arcs, the summits of sunk islands, and are arranged in semi-circular alignment not because they are islands, but because they are mountains. They may have been pushed up by over-thrusting of the land or by under-thrusting of the ocean floor. That, at any rate, is the theory (Philip Lake). But here we come back to the vexed question of mountain-building with which we are not concerned.

XVI

THE GEOGRAPHER AND ATOMIC ENERGY

'At last mankind has a method of landscaping the Earth and making profound geological changes. Deserts and arid regions of the world may blossom.'
Professor M. L. OLIPHANT (as reported)

IN so far as atomic energy may greatly affect the movements, numbers and distribution of mankind, it is already of indirect interest to the geographer. Now at one jump it comes into his direct field of view. The strategic, ethical and economic implications of atomic energy we can as yet but dimly perceive; nor are these things his immediate concern. But Professor Oliphant promises us structural alterations, material, geographical results, on an unprecedented scale, and the geographer is bound to ponder his words deeply. He is also entitled to comment on them, though cautiously.

We know that inconceivably great geological changes have taken place in the past, but in general so slowly that it required millions of years to complete each cycle. Most of these great changes were completed long before man appeared on the Earth, although far from insignificant changes have also taken place during the last quarter of a million years, since his arrival. And they are still continuing. But even these have taken so long, as compared with the life of a human generation, to produce obvious effects that mankind has had no great difficulty in adjusting himself to the slowly-changing landscape.

And now? With the threat of geological changes taking place in a flash, so to speak?

Let us therefore examine Professor Oliphant's statement in detail. But first it may be helpful to suggest briefly some of the possible broad effects of this new power, in an attempt to set it

in its true perspective, for the reports of the first atom bomb which fell on Japan have sobered if they have not shocked all thinking people the world over Atomic energy, if it can be harnessed and controlled like electricity, must have, by reason of its application to industry, profound political and social consequences, it will revolutionize our way of life

These far reaching results cannot, of course, be separated in air tight compartments They will interact, nor is it possible to gauge the net result to the human race Sir Lawrence Bragg has compared the discovery of atomic energy with the discovery of fire We need not follow the implications of that observation here, but it might be remarked that the discovery of fire was the most important, if not the only major discovery which separated non man from man, the next comparable step logically would be from man to superman

Now the geographer as such is not concerned with social and political changes, though he cannot afford to neglect them altogether He holds a watching brief on all that concerns mankind But with economic changes which will directly influence millions of human beings he is deeply concerned

If, for example, atomic energy becomes widely available, so that, as Professor Oliphant is reported to have said, a car could be driven 12,000,000 miles by one pound of uranium, great numbers of industrial workers will have a great deal more leisure than they have now What are they going to do with it? Comparatively few people know how to spend extra leisure hours to their own lasting benefit or anyone else s The majority are dependent on the toil of others for their amusement, and on public holidays in the West heavy demands are made on transport workers, the catering trade, professional entertainers, the police, and other sections of the population Here indeed is something the East can teach the West, if the West will learn Public holidays in India, Burma and China are enjoyed more simply, by everybody attending fairs and markets, visiting friends, picnicking, and seeing the temples, with a minimum call on the services of others In the West this

inability to enjoy ourselves by ourselves is becoming a disease

It is not confined to any one stratum of the population The 'idle rich' may not be an entirely meaningless phrase, but the chief difference between the idle rich and the idle poor is that the former require and can pay for the services of more people for longer periods to keep them amused

We all like to feel fresh for our work, but too long a holiday is apt to pall If we have regular work, by the time our leisure hours come round we are tired mentally and bodily and are only too willing to rest On holiday, however, we feel more energetic

And suddenly atomic energy bursts upon us Our position as regards work and leisure may be reversed Instead of eight hours' work a day and three hours' leisure we are threatened with two or three hours' work and eight hours' leisure What are we going to do with it?

No doubt it will be some years yet before industry, even in the most highly industrialized countries is run mainly by atomic energy and perhaps by that time we shall be better organized socially and better able to cope with our increasing leisure But that is by no means certain

Now that atomic bombs are definitely potential weapons of war the strategic consequences will be no less revolutionary For the first bomb which strikes home may decide the war Some people have argued that the atomic bomb will never be used even if, unhappily, another war does break out The consequences they say would be too awful They point to poison gas in the Great War and remind us that though every warring nation had large quantities of poison gas ready for the last war, not one of them used it The same thing they maintain will happen with atomic bombs Alas! it was not humanitarian reasons which kept the nations from using poison gas The consequences would indeed have been too awful — for the first users For no nation was ever in a position to use it without risk of heavy reprisal Nobody dared be the first because unless they were also the last they might receive better than they gave

That was the sole reason why gas was not used in the late war. Had any nation seen a chance of winning the war outright by using poison gas, it would have used it with no more scruple than the United Nations used atomic bombs It is the same principle as the old balance of power which kept the peace of Europe for forty years The United Nations used the atomic bomb because they had it and nobody else had. It is highly unlikely that such a situation will soon arise again We may be sure there will not be another world war until all the great nations know the secret of the atomic bomb

Atomic energy is so powerful in annihilation that concentration on any big scale whether of men, machines, weapons, supplies, ships, buildings, or anything else will be impossible. As always, the best defence will be offence against the source of the bombs, or, better still, to ensure that they are never made. Unless that is done a terrible sword hangs over the head of the unready nation — nothing less than the threat of extermination No tree, building, or hill would be left standing in an area where enemy troops were believed to lurk. The place would be swept shadowless Camouflage would be useless, and in fact impossible. Also in any future war mere manpower, however great, would not be a factor of major importance. War may become an affair of highly-trained guerillas, widely scattered over huge spaces Hence the mountains are likely to become once more a refuge, and a movement towards them is already setting in. We may note that Japan, Java and Burma are all mountainous countries.

A disservice was done to mankind by the announcement that the secret of the atomic bomb would be kept. That bred fear, not confidence. Some of the very same people who urged that the secret of the bomb itself *ought* to be kept, at the same time urged that atomic energy should be available to all for industrial use. Yet it should be obvious that what can be used in peace can be turned to war. Once use atomic energy in industry and the secret is out.

Apart from that atomic energy can no longer be kept secret,

and the more one nation tries to keep it dark the more intensively will other nations pursue their researches and the sooner will every nation which has the resources solve it That means India, China and Japan, as well as France, Russia and Germany For the atomic bomb is the climax to half a century's work in atomic physics, to which many nations and hundreds of research workers contributed The principle of atomic energy is common knowledge amongst physicists in every western land It is international, and the solution of technical difficulties is merely a question of time

As geographers, however, we are not concerned with matters of policy any more than with industry, economics or war— though it might be an advantage if the Army Command were more geographically minded I have mentioned these matters so that the reader may clearly perceive some of the issues involved What concerns us immediately as geographers is the direct influence of atomic energy on the material world, the greatest and perhaps the last step in the long slow march from human muscle power, animal muscle power and machine power, to atom splitting as a source of industrial energy Now there seem to be two ways in which the atom bomb or mine might 'landscape' the Earth — that is, alter its topography (1) by reshaping the physical landscape directly, (2) by altering the climate Either or both of these methods are implicit in Professor Oliphant's statement quoted at the head of this chapter

(1) The landscape could be changed in a number of ways, as, for example, by digging huge craters which might become lakes, by levelling hills, damming or diverting rivers blowing up glaciers draining lakes, digging canals, in fact, by doing easily and quickly many things which are done slowly and painfully by man to day, or which are done at a blow by nature at longer or shorter intervals None of these, however, are more than minor topographical alterations Nor can it be maintained that the effects which have been produced during the last five hundred years, say, by nature in violent mood are

more than scratches on the face of the Earth They have no more than a local significance except on the largest scale map even the greatest disaster is imperceptible Floods, typhoons, earthquakes, tidal waves volcanic eruptions, the impact of meteors, and other forces all have to some extent landscaped the Earth Yet in a bird s eye view the Earth seems very much like what it was five centuries ago and this in spite of ceaseless wear and tear and reconstruction The results of violence, though often spectacular for a short time, especially when accompanied by loss of human life, are hardly of fundamental importance It can be faintly imagined therefore how much atomic energy must be released to produce big changes of scenery Far more important than any violence so far witnessed by man are the slow geological changes which result from long continued action But here time must be measured in tens of thousands of years rather than in centuries

However, it is only when the loss of life is grievous that the majority of people become momentarily aware of nature s aggression Many of her swift blows are not recorded at all, they are neither seen nor felt Of those which become generally known only a small number are headline news Thus the Krakatoa explosion and the almost equally violent eruptions of Mont Pelée and of Vesuvius the Messina and the Japanese earthquakes were quickly known and attracted attention all over the world Not so the Kansu earthquake of 1920 in which thousands were killed, nor the Siberian meteorite impact a few years later when apparently no one was killed Had the Siberian meteorite hit London or Moscow it must have had much the same effect as the atomic bomb on Hiroshima Still less did the world hear of the Arizona meteorite, or of the great Arabian meteorite, both of which struck the Earth probably some centuries ago and crashed into the desert

Many big meteorites no doubt fall into the sea and many submarine volcanic explosions pass almost unnoticed because there is no loss of human life However, there can be no doubt that catastrophes *do* occur, and will occur again, though from

the geographical standpoint they may be of less importance than others which cause little or no loss of life

It would seem then that we must not expect any swift re shaping of the Earth as a result of atomic energy We are not likely to see troublesome islands made to disappear, continents cut in half, mountain ranges smoothed out, or new seas brought into existence just yet Such things are no doubt theoretically possible But long experience teaches us that for various reasons cultures spread slowly, nor is the use of atomic energy in everyday life likely to be any exception It is the *products* of the machine, not the machine itself, which nowadays spread far and wide Perhaps the machine to-day spreads faster than, say, bronze did 4000 years ago when in the Middle East a Neolithic flint culture overlapped it by a thousand years One has only to look round the world to-day to see that industry, as represented by the power engine, is concentrated in only a small proportion of the land surface The great majority of cultivators all over the world still use hand made ploughs These matters are largely governed by factors at present out side man's control — the distribution of raw materials, for example, and climate

Nevertheless, at a few selected points atomic energy may become available Atomic mines might be used for blowing up awkward reefs which have long been a danger to shipping, ridding rivers like the Mekong of dangerous rapids, and so on Indeed, in certain parts of the world the atom mine might bring about useful results which otherwise might take years, or which might not be worth doing at all In a few places conditions are such that landscaping on a big scale would be possible, though whether for good or evil it is impossible to say In South East Asia the gorges of the big rivers could be swiftly blocked, forming enormous lakes behind the dam In front, the river would drain away, dwindle to little or nothing This would make changes on a territorial scale, especially if the dam suddenly gave way, releasing billions of tons of water There would, indeed, be landscaping of the Earth, chiefly destructive!

Raising the water level behind the dam even a few hundred feet would enable a considerable area of land to be terraced and irrigated By damming the Salween at selected points, that now unused river might be turned to good account

Unless we have greatly underrated controlled atomic power — uncontrolled it would run amok — we cannot expect for a long time yet to landscape the Earth

There remains the possibility of influencing the climate or altering the weather notably by bringing rain to some of the drought stricken areas of the Earth as indicated by Professor Oliphant

Before we discuss this possibility we need to have a general understanding of the factors which control climate and what the effect of an explosion really is It is also an advantage to be quite sure what we want to do If we merely reply, to bring rain the doubter will at once ask, How much rain? For how long? Where will it fall? Nor can we give a straightforward answer First then how is rain produced and where is it controlled?

All the rain that falls on the Earth came from the Earth by evaporation from lakes rivers and particularly the oceans This invisible vapour ascends with the air currents and is carried away by more or less constant air streams Over the land it tends to rise higher than over the sea in the same latitude, nowhere does it rise higher than about seven miles above sea level that is to the limit of the trophosphere

When cooled below a certain temperature differing with the degree of saturation the vapour condenses as visible cloud. Cloud consists of drops of water so finely divided that they remain suspended in the air But under conditions which frequently occur notably a lowering of temperature or an increase in the amount of water vapour present in a given volume of air the finely divided drops of water begin to join together into larger drops until at last they grow so big that the atmosphere can no longer support them Then they fall as rain

Given the sun's heat — the source of all energy — world climatic belts are due primarily to four causes (1) the fact that the Earth revolves round the sun, rotating at the same time round an axis tilted so as to make an angle of 23½ degrees with the vertical to the plane in which it revolves This causes the primary temperature belts between equator and Poles (2) The distribution of land and sea with the resulting unequal heating of the atmosphere, which causes currents to flow, and of course unequal evaporation (3) The rotation of the Earth on its axis which gives a constant direction or change of direction to these currents, and (4) The unevenness of the land surface which causes rapid vertical changes of temperature and also interposes barriers against the air currents which are diverted or forced to rise

A fifth factor, though perhaps a minor one, is the presence of ice at the Poles — fixed cold as it might be called The South Pole being a high land area would have fixed cold anyhow The North Pole is covered by water and if this were fluid instead of solid, a degree or two above freezing point, for example, it would make an enormous difference to the climate of the northern hemisphere [1] However, one might say the same thing about any of the conditions We must take the Earth as we find it, not as it might be

It is an open question whether, the above factors remaining more or less as they are, any substantial alteration in the total rainfall of the Earth is possible Its distribution might be altered but not perhaps its amount Of the above four motive powers, 1 and 2 are chiefly concerned with the amount of evaporation and hence with the actual rainfall, 3 and 4 with the circulation, direction and strength of air currents and hence with the distribution of rainfall

It will be observed that all four are more or less constant, not in geological or astronomical time, for they do change, though with infinite gradualness, but in historical time As a result the main air currents are likewise more or less constant,

[1] Brooks *Climate Through the Ages*

from which we might infer that the world climates are more or less fixed Observation confirms this, although considering the fluid nature of the atmosphere it is a matter for surprise

We know that climatic revolutions have taken place in geological time over and over again, but we also know that climates have been comparatively stable in a given area through vast ages Is atomic energy about to upset this order, and bring about quick change? Let us see what nature has to say

The only natural disaster, short of a planetary collision or the impact of a big meteorite on the Earth, comparable with the atomic bomb is a volcanic eruption Many big eruptions have been witnessed by man and their effects recorded Within the last seventy years Krakatoa in Sunda Strait, Vesuvius, Mont Pelee and other volcanoes have burst like huge boilers Accounts of early eruptions have come down to us We know a good deal about the last days of Pompeii in A D 79 When a volcano is in violent eruption enormous volumes of steam and 'smoke' are shot several miles into the air The belief is widespread all over the Earth that a loud noise produces rain It is true that rainstorms usually follow a volcanic eruption But this is only natural when we recollect that pent up steam in the Earth's crust is at least partly responsible for the eruption Issuing at high pressure, it reaches a great altitude where in a colder stratum of air it condenses in the usual way to form cloud and descend as rain

Thus the volcano itself provides the rain it is alleged to conjure out of space Submarine explosions are not accompanied by rain

Some time after the island of Krakatoa blew up it was reported that a series of remarkably brilliant sunsets were being observed all over the world These were said to be due to fine dust shot into the upper strata of the atmosphere and carried round the world by currents The evidence for this, however, is inconclusive It has been objected for example that in South Africa the same brilliant sunsets were noticed

before the explosion, which, if true, would destroy the whole argument Moreover, it is at least doubtful whether air currents *would* carry the dust all over the world Air currents, like sea currents, keep to certain tracks It is curious that the sunset effect has not been recorded after any other eruption Vivid lightning, caused perhaps by friction as steam and dust are forced up through the vent, accompanies the rain, which is a feature of most eruptions on land But as we have just said, it is not the explosion which causes the rain

It may be observed that on land volcanic eruptions always take place within the trophosphere and usually within three or four miles of sea level In the Andes there are a few volcanoes over 20,000 feet high, but these are exceptional What results might follow the explosion of atomic bombs in the stratosphere, say 10 or 12 miles up, is unknown, but there is no reason to suppose it would affect the weather Anyhow, to avoid damage bombs would have to be exploded at a great height

Those who still cling to the belief that explosions bring rain refer to the gunfire in Flanders in 1917-18, and also to deliberate experiments in several countries The heavy gunfire in France and Flanders in the Great War was accompanied by, followed by, and also preceded by, rain as it was by sunshine The heavens never wept for the slain There was nothing abnormal in the weather but everybody remembered the mud The argument that gunfire caused the rain is no more valid than the argument that gunfire caused the sunshine *Post hoc, ergo propter hoc* is an old pitfall

As to the experiments, they all failed to produce rain by noise or explosion, and it can be stated categorically that rain has never yet been produced by this means, and so far as one can foresee it never will Though atomic bombs with the explosive energy of 2,000,000 tons of T N T are already promised, a severe volcanic eruption, whether or not it releases the energy of an atomic bomb, is quite violent enough to make rain if rain could be made thus We know that it cannot, nor will the atomic bomb succeed where the volcano fails

The explosion of atomic mines beneath the sea might conceivably furnish the water vapour necessary to produce rain, although if it fell back into the sea it would be wasted But the prospect of getting it high enough into the air to cool it rapidly and at the same time sufficiently concentrated to ensure its condensing is not bright For this purpose a volcano is peculiarly well suited It fires a jet of steam straight up into the air as though it were shot out of a gun The vent, in fact, is like the nozzle of a hose with a fire-engine pump behind it The fact that no submarine explosion has been known to produce 'weather' suggests that the method is not feasible Even if it were we should need to know much more about the direction, strength and permanence of the upper air currents before we could predict with certainty where the rain would fall

Those who have read Kipling's dramatic story of a submarine upheaval will remember how a dense mist shrouded the sea owing to the welling up of ice-cold water from the abyss to the surface, thereby cooling the moist air in contact with it below the dew point There was no visible explosion and no rain, only a dense white mist of vapour, made visible

The effect of an ordinary explosion is to produce a large volume of gas at a high temperature Released instantaneously in a confined space, the expanding gas liberates energy In the atmosphere, explosion produces a pressure wave followed by a partial vacuum which is violently filled up as quickly as it is formed owing to pressure of the surrounding air It is difficult to see why this sequence should create rain, no sudden heating and expansion of the air can make it produce what isn't there As for attracting cloud from outside an explosion would be more likely to dissipate it

There is an aspect of the atomic explosion which seems to have escaped general comment Apparently ruin is caused far more by the terrific heat evolved than by expanding gases, though the air itself must expand under the influence of heat. Violent agitation of the trophosphere will result in currents being sent up but with what result? We cannot say, and

therein lies the danger Until we can predict the result, and unless the effect is purely local, international complications might arise when countries start letting off atomic mines close to the frontier, to the detriment of their neighbour s weather Apart from the fact that loud bangs produce no rain, we have to consider that the total rainfall of the Earth is probably in equilibrium with the total heat received from the sun, the total evaporating surface, and the volume of the atmosphere If that is so then the only change that could be effected would be a change in distribution, and the gain in one place would be the loss in another Otherwise a change in the total rainfall could only be brought about very gradually by altering one or other of the above factors

The columns of swirling air which give birth to the Trade winds, Monsoons and other vast regular currents are of great bulk Even those which give origin to local weather are not small

No doubt most people who think they see in the atomic bomb a bit with which to ride the storm and direct the weather are thinking of the possibility of bringing rain to the enormous desert areas of the Earth Might it not be possible to resurrect the dead heart of Australia, for example? to bring back green pastures to the Sahara? to make Central Asia once more a Garden of Eden? The only possible reply is 'no' — not with atomic bombs

Let us look at a few figures Evaporation over the whole surface of the Earth has been estimated as equal to the evaporation of a layer of water 3 feet deep over that surface in a year (C R Benstead) It is probably far greater than that in the sub tropical desert belt, only there is not 3 feet of water there, or even 3 inches to be evaporated On the other hand evaporation is almost nil at the Poles The estimate includes evaporation from lakes rivers, and from vegetation — all land based water, as well as from the sea

In a typical Monsoon region (Upper Assam for example where I am writing) the annual rainfall is about 95 inches,

most of which falls in five months That is to say, every acre of land receives over 9000 tons of rain a year Hence a tea garden covering 600 acres gets some 5 000 000 tons of water poured on to it in six months Much of this serves merely to keep the air constantly humid but there is also a big run-off, some of which is wasted so far as the surrounding vegetation is concerned Nevertheless, without a rainfall of that order neither rice nor tea could be grown in the hot Assam valley without irrigation

The Sahara covers about 3½ million square miles Here too evaporation is exceptionally high A 90 inch rainfall all over would mean 20 million tons of water a year Yet if that amount were supplied through irrigation channels most of it would evaporate before it reached the fields It might require three or four times that amount before the vegetation got as much water as it gets in Assam

It is, of course in connection with agriculture that rain is most needed, and an increase rather than a redistribution is needed Large areas do not get enough rain to grow crops As we saw in Chapter VIII, two-fifths of the land surface of the Earth is unfit for agriculture About 11 million square miles is too dry, the remainder is too wet or too cold or too salt. Over a million square miles is too wet, resulting in the formation of peat It might be more advantageous to lessen the rainfall here than to increase it elsewhere, although as we have seen it might be impossible to do the one without at the same time doing the other But neither will be done by atomic bombs increasing or diminishing the rainfall The one thing that atomic energy might do towards a more equal distribution of rainfall would be the making of vast inland seas like the Caspian, either by damming rivers or by excavation No doubt the unequal distribution of many minerals and especially water is responsible for some of the world s ills But would it not be truer to say that man has prospered and increased chiefly in those areas where nature's gifts, especially water, are found in abundance?